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Ishiyama et al.

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(54) **REFRIGERATION CYCLE APPARATUS**

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(73) Assignee: **Mitsubishi Electric Corporation**, Tokyo (JP)

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F25B 49/02 (2006.01)
(Continued)

(52) **U.S. Cl.**

CPC ***F25B 13/00*** (2013.01); ***F25B 31/004*** (2013.01); ***F25B 40/00*** (2013.01); ***F25B 41/04*** (2013.01);
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(58) **Field of Classification Search**

CPC F25B 31/004; F25B 47/025; F25B 13/00; F25B 40/00; F25B 41/04; F25B 49/02;
(Continued)

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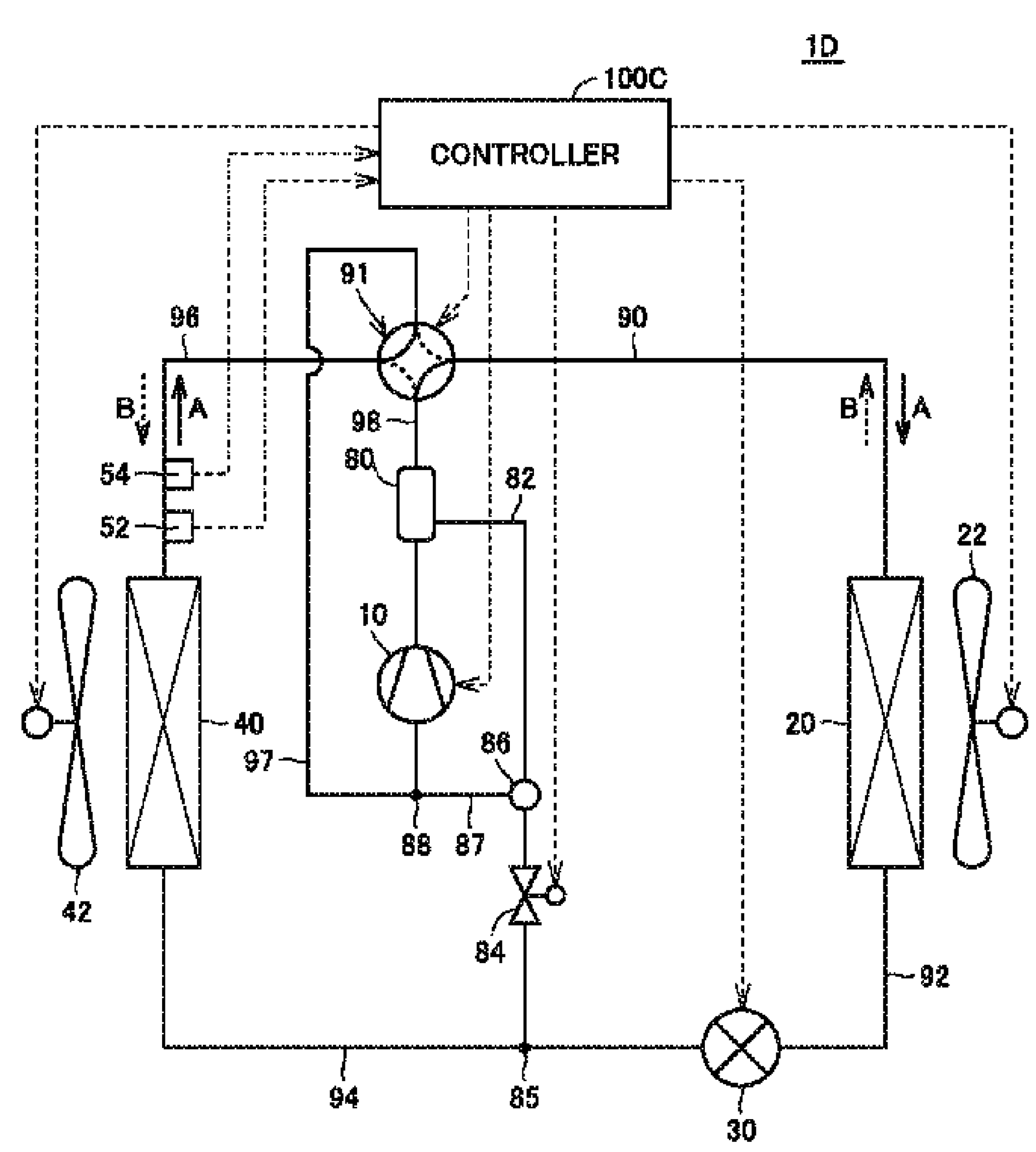
(57) **ABSTRACT**

A refrigeration cycle apparatus includes a compressor, first and second heat exchangers, an expansion valve, a four-way valve, and a controller. The four-way valve is configured to switch a direction of flow of the refrigerant between a first direction and a second direction. The controller is configured to control the four-way valve to switch an operation from a defrosting operation in which the refrigerant flows in the second direction, to a heating operation in which the refrigerant flows in the first direction, to perform a heating preparation control for increasing a degree of superheat of the refrigerant output to the compressor from the second heat exchanger, and thereafter to start the heating operation.

5 Claims, 17 Drawing Sheets



(51) **Int. Cl.**
F25B 41/04 (2006.01)
F25B 31/00 (2006.01)
F25B 47/02 (2006.01)
F25B 40/00 (2006.01)

(52) **U.S. Cl.**
CPC ***F25B 47/025*** (2013.01); ***F25B 49/02*** (2013.01); *F25B 2313/0313* (2013.01); *F25B 2313/0315* (2013.01); *F25B 2600/21* (2013.01); *F25B 2600/2501* (2013.01)

(58) **Field of Classification Search**
CPC F25B 2600/21; F25B 2313/0315; F25B 2313/0313; F25B 2600/2501; F25B 43/02
See application file for complete search history.

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FIG.1

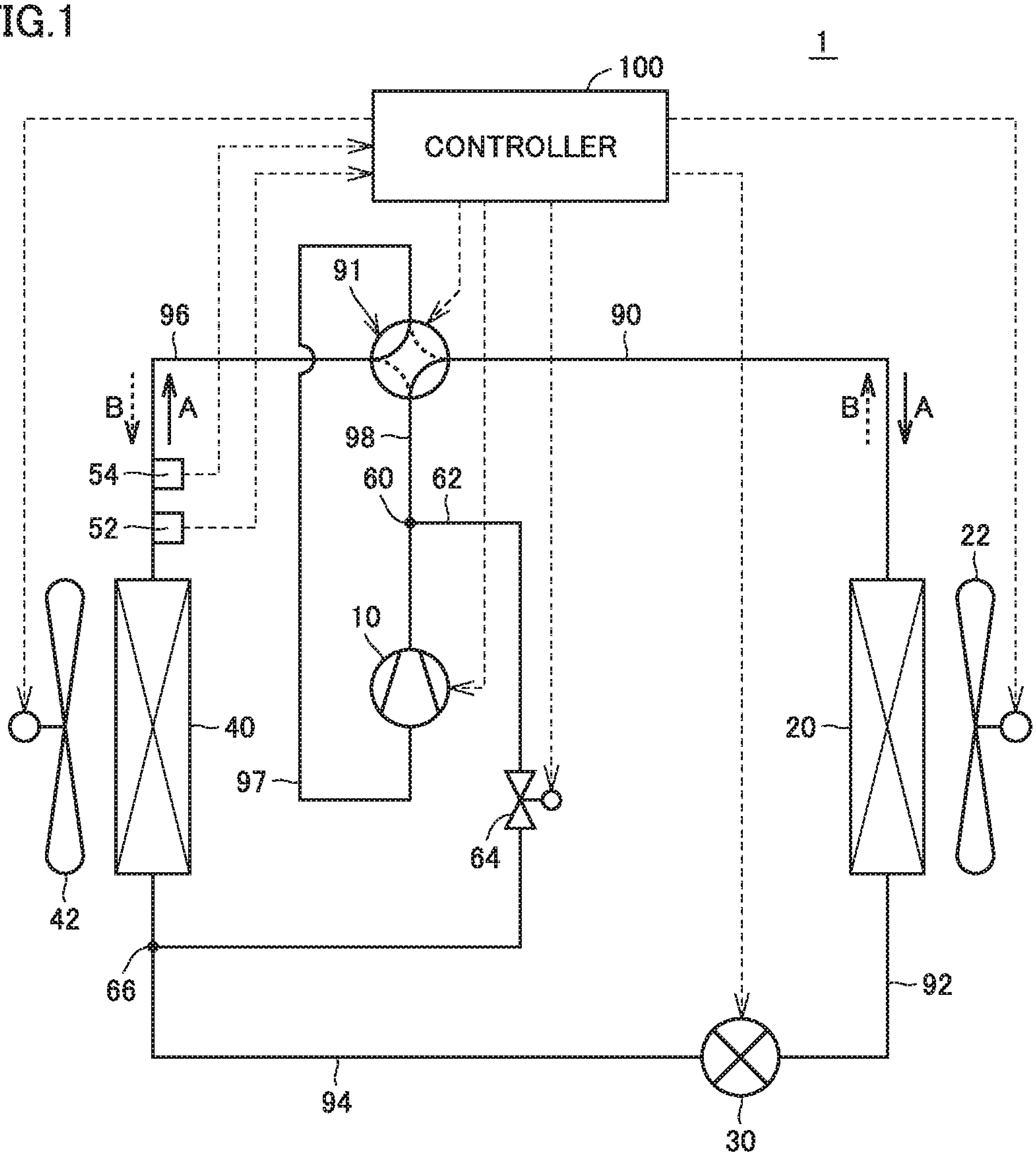

1
100
CONTROLLER
91
96
90
B
A
B
A
98
54
60
62
52
22
10
40
20
97
64
42
66
92
94
30

FIG.2

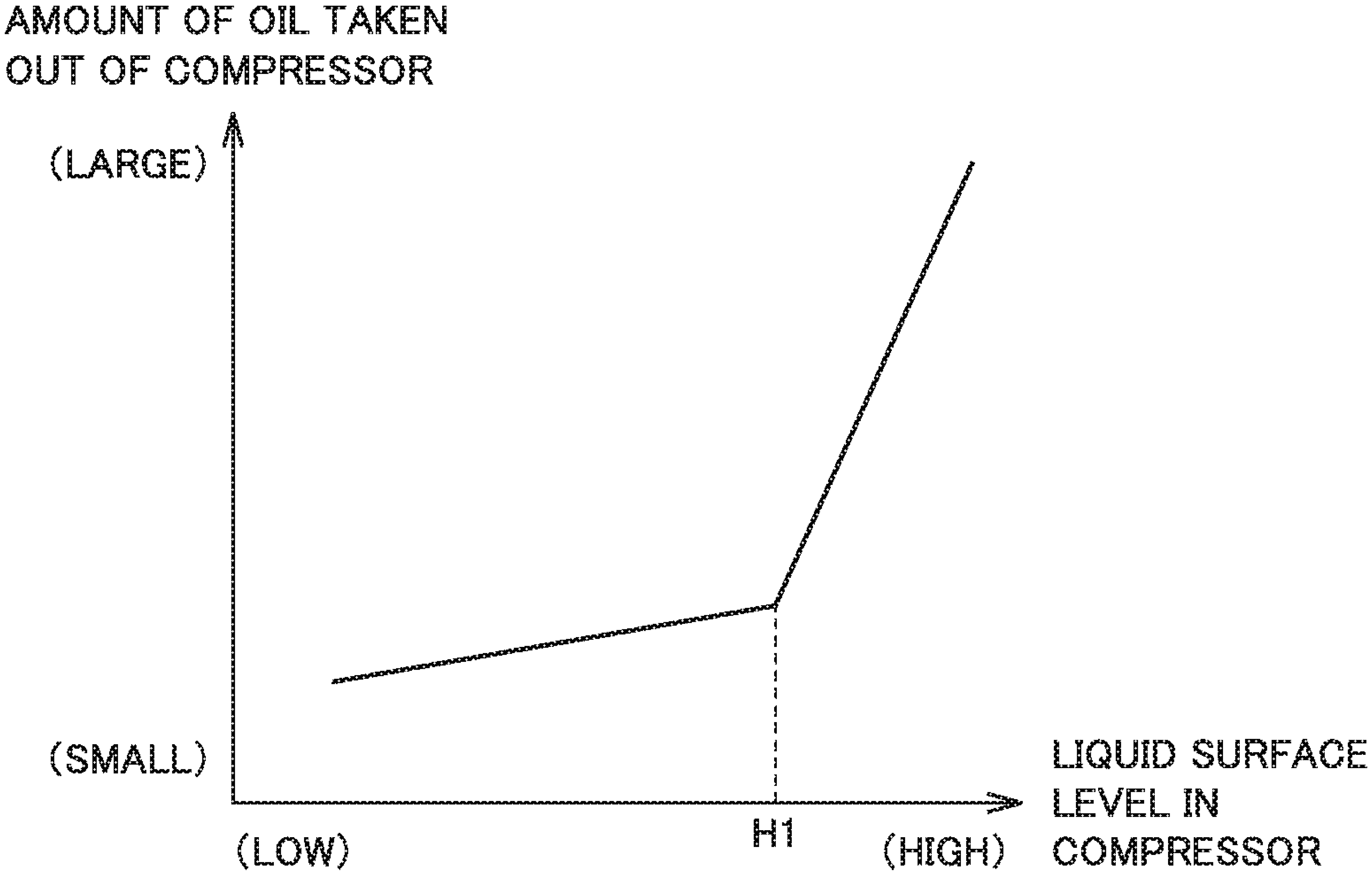

AMOUNT OF OIL TAKEN
OUT OF COMPRESSOR
(LARGE)
(SMALL)
(LOW)
H1
(HIGH)
LIQUID SURFACE
LEVEL IN
COMPRESSOR

FIG.3

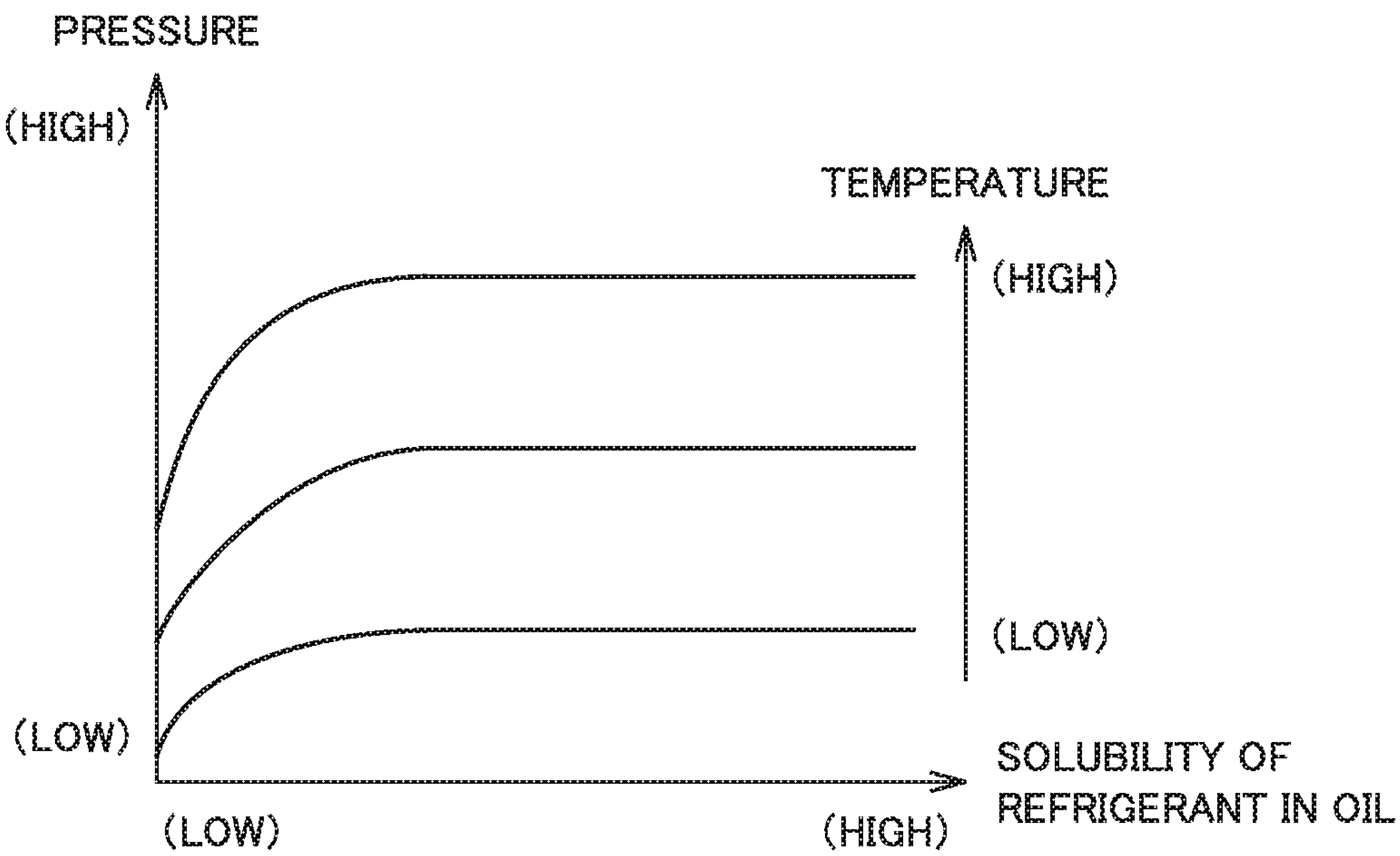

PRESSURE
(HIGH)
(LOW)
TEMPERATURE
(HIGH)
(LOW)
(LOW)
(HIGH)
SOLUBILITY OF
REFRIGERANT IN OIL

FIG.4

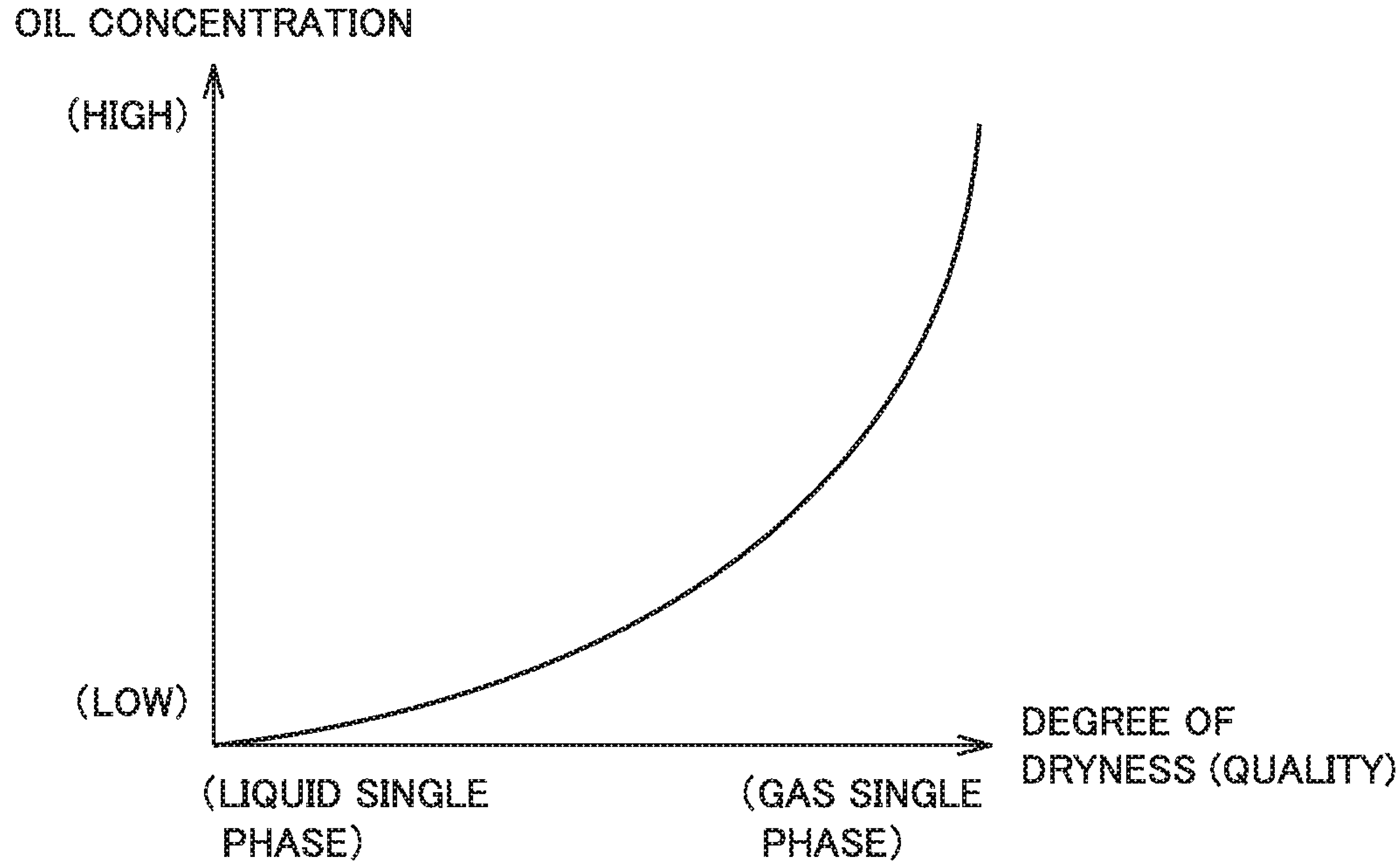

OIL CONCENTRATION
(HIGH)
(LOW)
DEGREE OF DRYNESS (QUALITY)
(LIQUID SINGLE PHASE)
(GAS SINGLE PHASE)

FIG.5

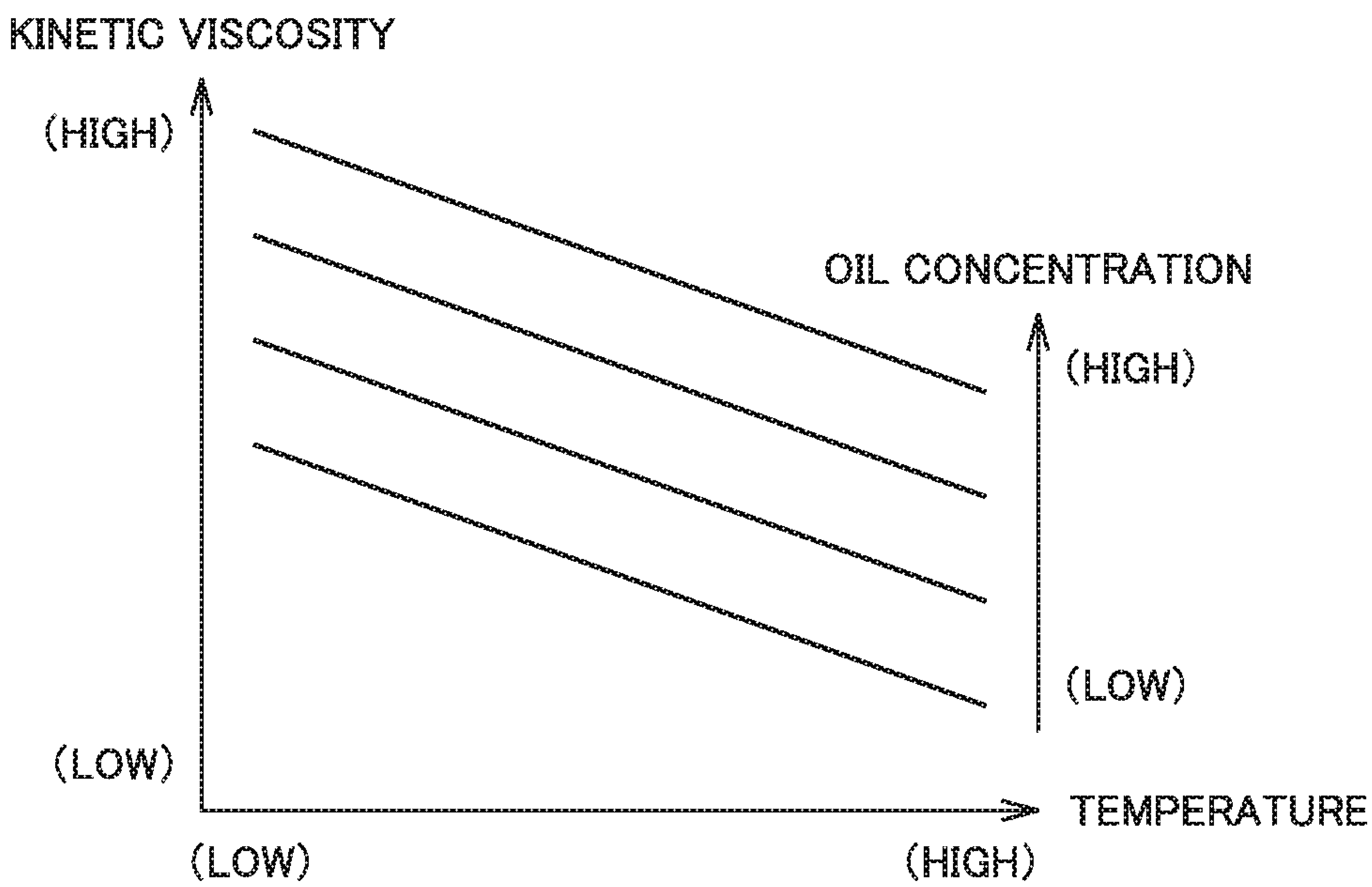

KINETIC VISCOSITY
(HIGH)
(LOW)
OIL CONCENTRATION
(HIGH)
(LOW)
TEMPERATURE
(LOW)
(HIGH)

FIG.6

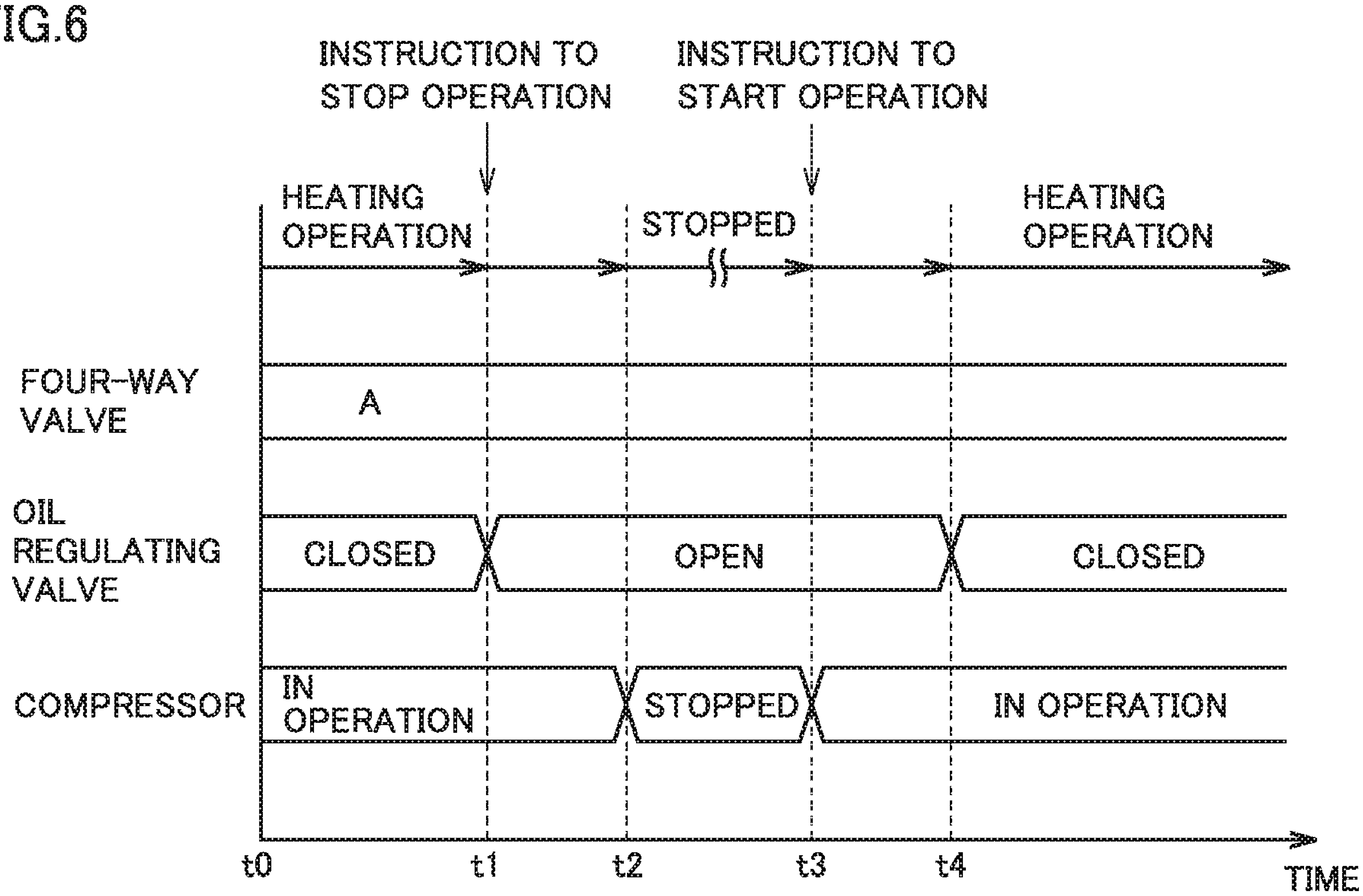

INSTRUCTION TO STOP OPERATION
INSTRUCTION TO START OPERATION
HEATING OPERATION
STOPPED
HEATING OPERATION
FOUR-WAY VALVE
A
OIL REGULATING VALVE
CLOSED
OPEN
CLOSED
COMPRESSOR
IN OPERATION
STOPPED
IN OPERATION
t0
t1
t2
t3
t4
TIME

FIG.7

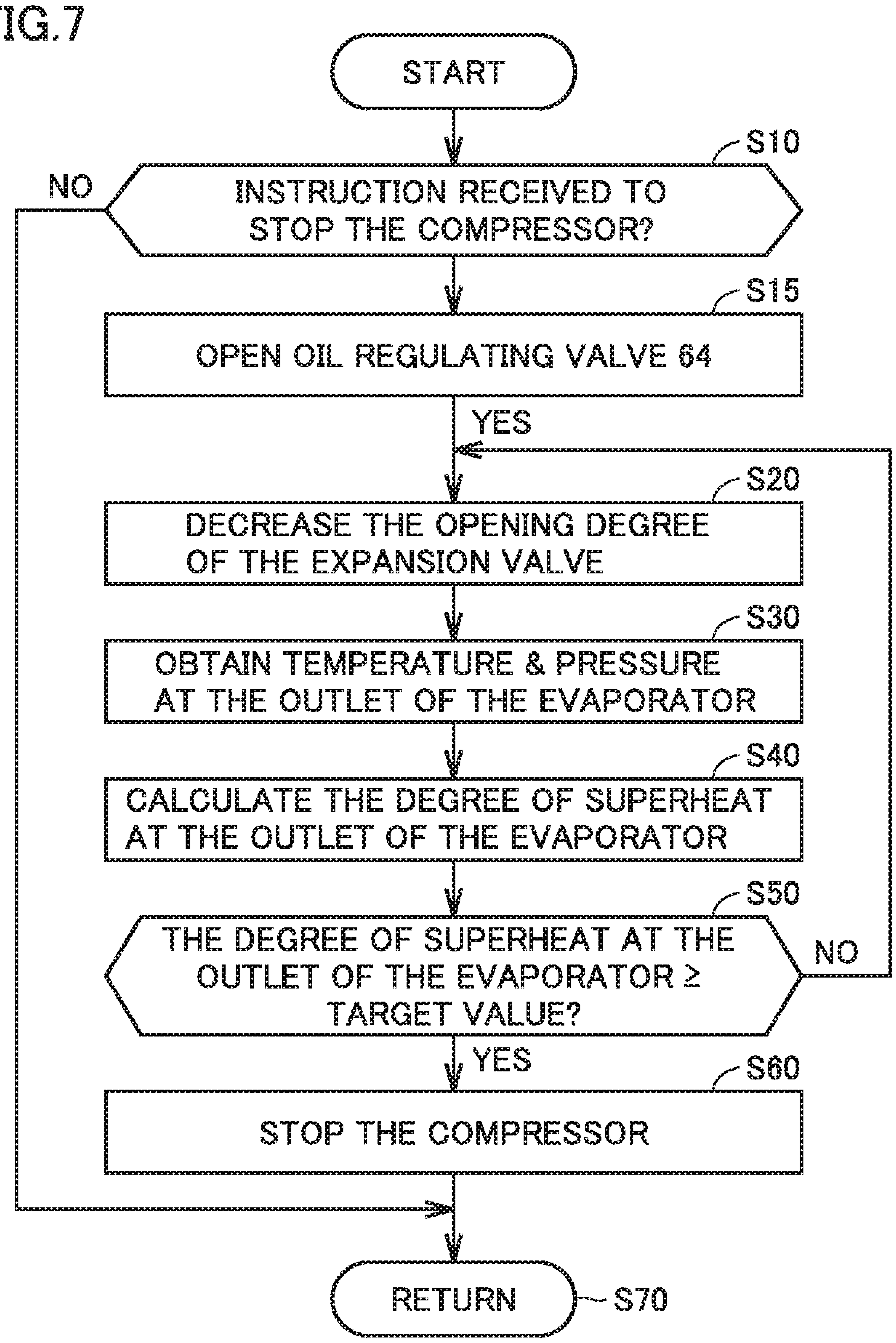

START
S10
INSTRUCTION RECEIVED TO STOP THE COMPRESSOR?
NO
S15
OPEN OIL REGULATING VALVE 64
YES
S20
DECREASE THE OPENING DEGREE OF THE EXPANSION VALVE
S30
OBTAIN TEMPERATURE & PRESSURE AT THE OUTLET OF THE EVAPORATOR
S40
CALCULATE THE DEGREE OF SUPERHEAT AT THE OUTLET OF THE EVAPORATOR
S50
THE DEGREE OF SUPERHEAT AT THE OUTLET OF THE EVAPORATOR ≥ TARGET VALUE?
NO
YES
S60
STOP THE COMPRESSOR
RETURN
S70

FIG.8

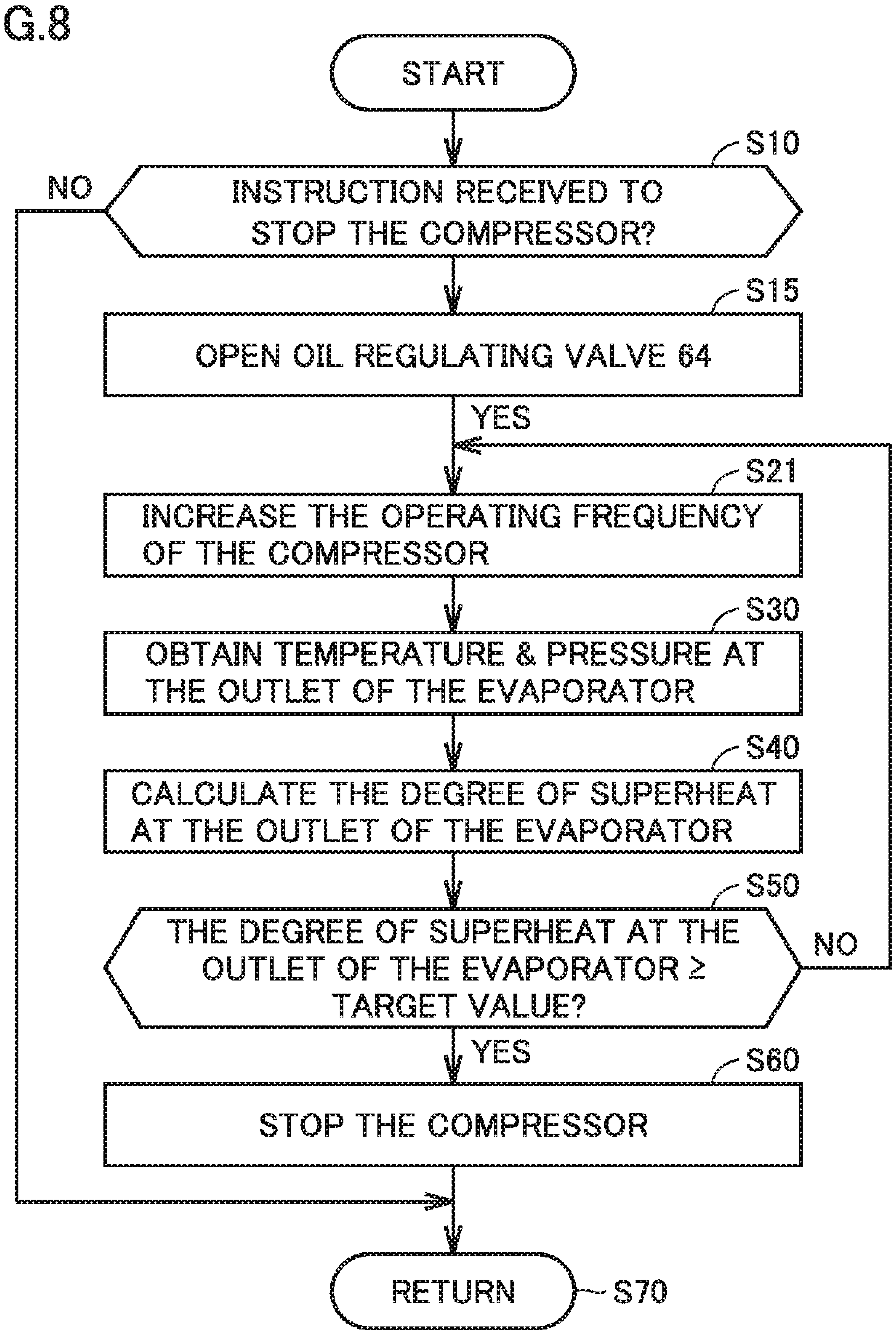

START
S10
INSTRUCTION RECEIVED TO STOP THE COMPRESSOR?
NO
S15
OPEN OIL REGULATING VALVE 64
YES
S21
INCREASE THE OPERATING FREQUENCY OF THE COMPRESSOR
S30
OBTAIN TEMPERATURE & PRESSURE AT THE OUTLET OF THE EVAPORATOR
S40
CALCULATE THE DEGREE OF SUPERHEAT AT THE OUTLET OF THE EVAPORATOR
S50
THE DEGREE OF SUPERHEAT AT THE OUTLET OF THE EVAPORATOR ≥ TARGET VALUE?
NO
YES
S60
STOP THE COMPRESSOR
RETURN
S70

FIG.9

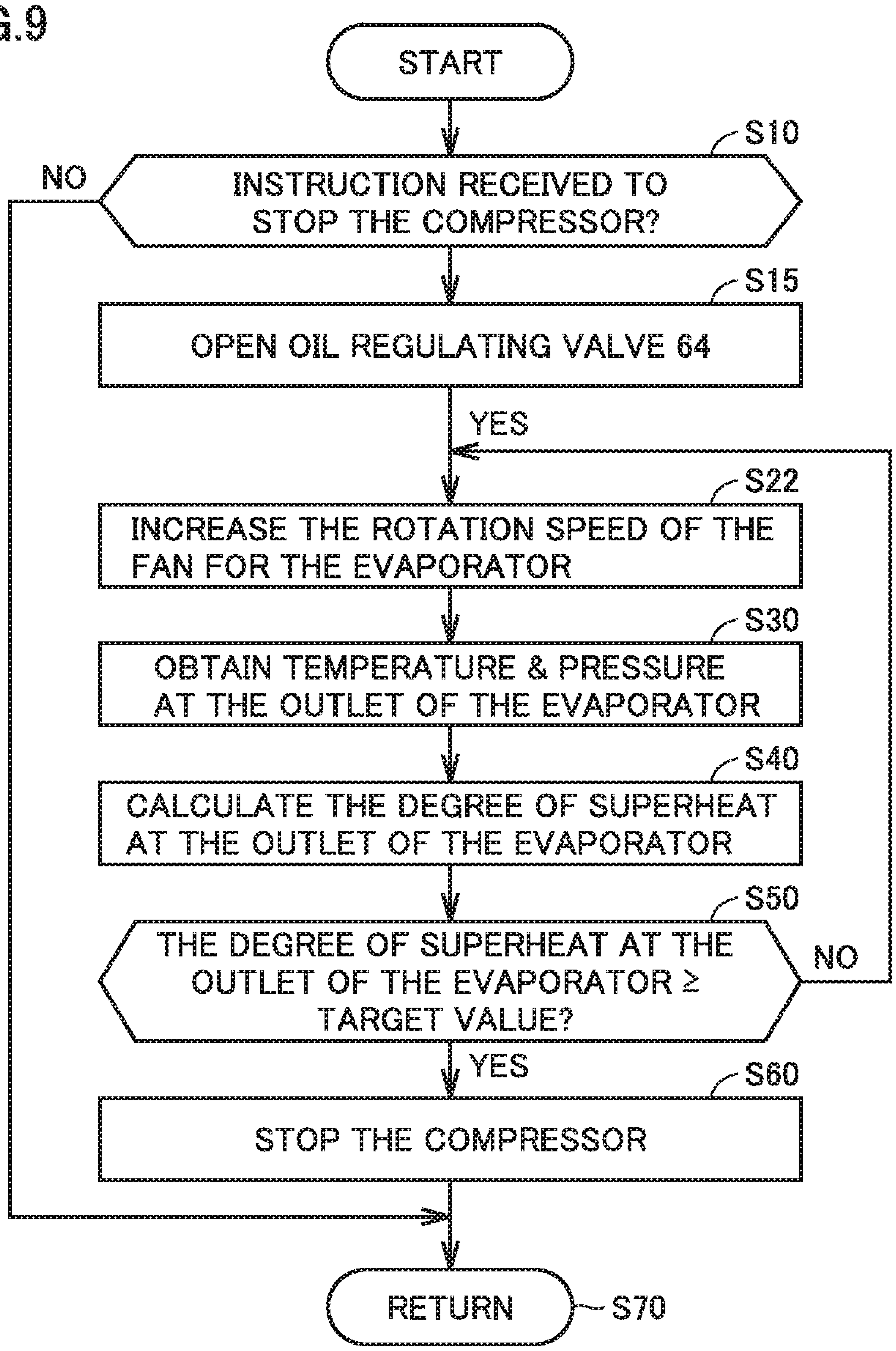

START
S10
INSTRUCTION RECEIVED TO STOP THE COMPRESSOR?
NO
S15
OPEN OIL REGULATING VALVE 64
YES
S22
INCREASE THE ROTATION SPEED OF THE FAN FOR THE EVAPORATOR
S30
OBTAIN TEMPERATURE & PRESSURE AT THE OUTLET OF THE EVAPORATOR
S40
CALCULATE THE DEGREE OF SUPERHEAT AT THE OUTLET OF THE EVAPORATOR
S50
THE DEGREE OF SUPERHEAT AT THE OUTLET OF THE EVAPORATOR ≥ TARGET VALUE?
NO
YES
S60
STOP THE COMPRESSOR
RETURN
S70

FIG.10

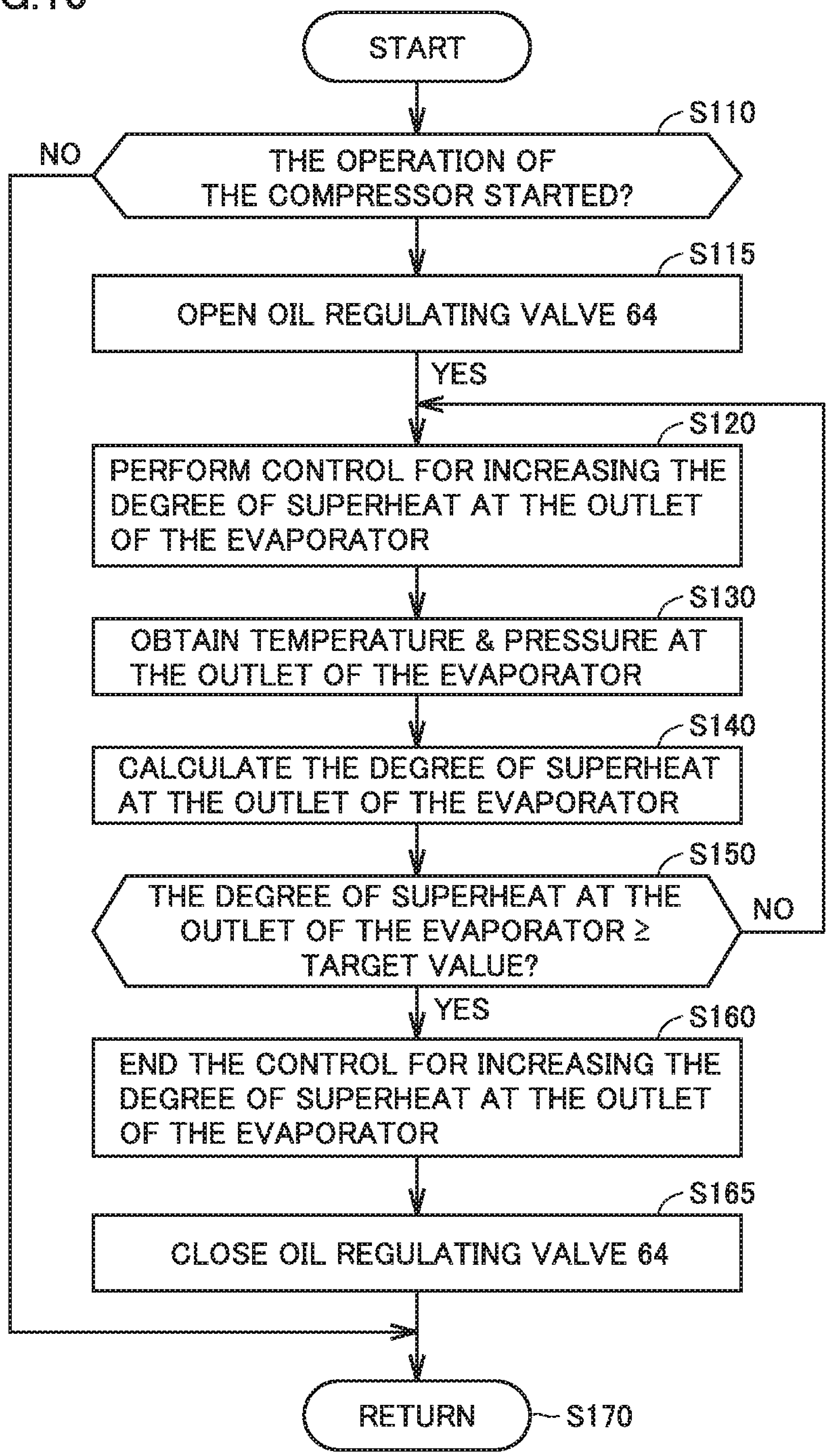

START
S110
THE OPERATION OF THE COMPRESSOR STARTED?
NO
S115
OPEN OIL REGULATING VALVE 64
YES
S120
PERFORM CONTROL FOR INCREASING THE DEGREE OF SUPERHEAT AT THE OUTLET OF THE EVAPORATOR
S130
OBTAIN TEMPERATURE & PRESSURE AT THE OUTLET OF THE EVAPORATOR
S140
CALCULATE THE DEGREE OF SUPERHEAT AT THE OUTLET OF THE EVAPORATOR
S150
THE DEGREE OF SUPERHEAT AT THE OUTLET OF THE EVAPORATOR ≥ TARGET VALUE?
NO
YES
S160
END THE CONTROL FOR INCREASING THE DEGREE OF SUPERHEAT AT THE OUTLET OF THE EVAPORATOR
S165
CLOSE OIL REGULATING VALVE 64
RETURN
S170

FIG.11

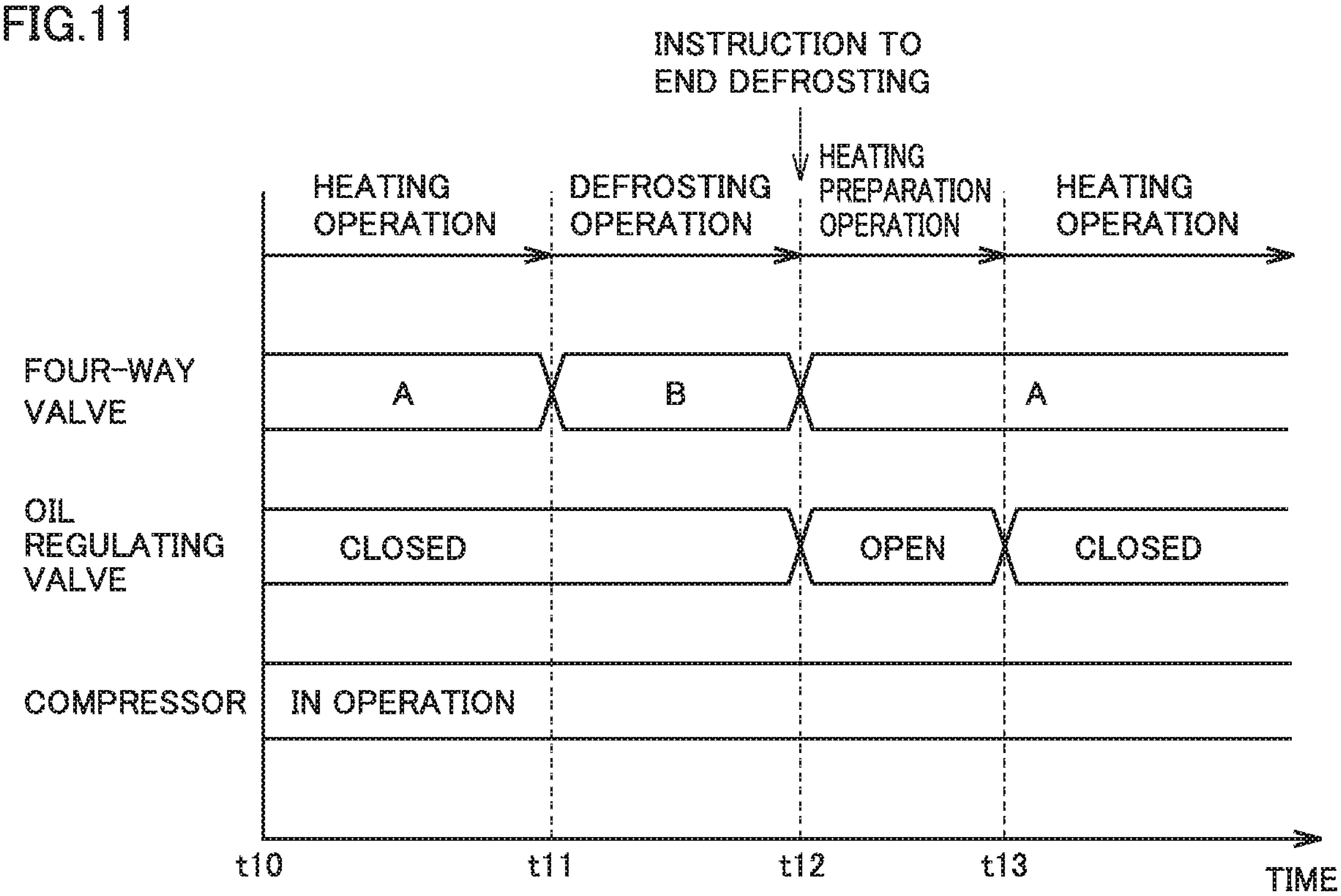

INSTRUCTION TO
END DEFROSTING
HEATING
OPERATION
DEFROSTING
OPERATION
HEATING
PREPARATION
OPERATION
HEATING
OPERATION
FOUR-WAY
VALVE
A
B
A
OIL
REGULATING
VALVE
CLOSED
OPEN
CLOSED
COMPRESSOR
IN OPERATION
t10
t11
t12
t13
TIME

FIG.12

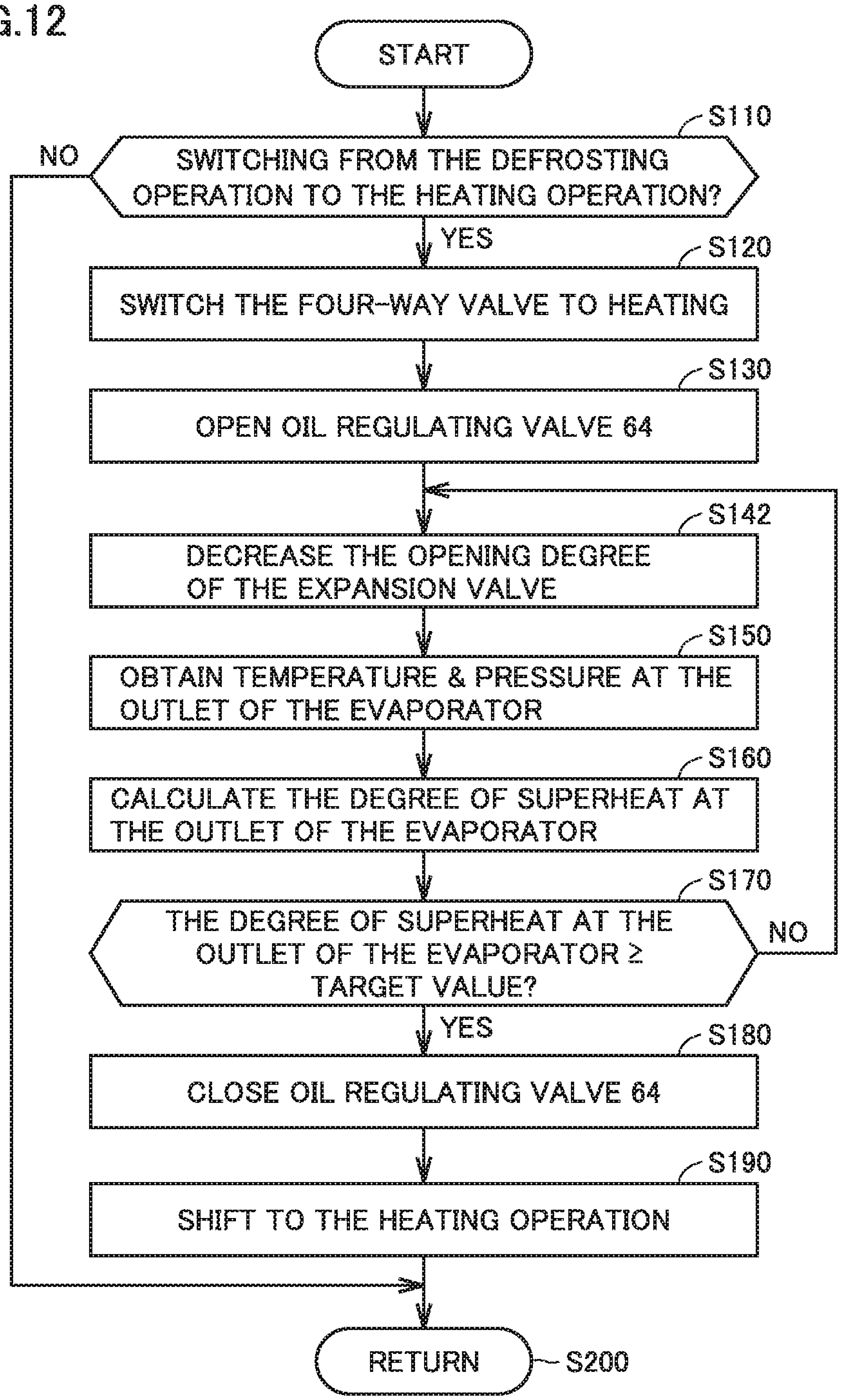

START
S110
SWITCHING FROM THE DEFROSTING OPERATION TO THE HEATING OPERATION?
NO
YES
S120
SWITCH THE FOUR-WAY VALVE TO HEATING
S130
OPEN OIL REGULATING VALVE 64
S142
DECREASE THE OPENING DEGREE OF THE EXPANSION VALVE
S150
OBTAIN TEMPERATURE & PRESSURE AT THE OUTLET OF THE EVAPORATOR
S160
CALCULATE THE DEGREE OF SUPERHEAT AT THE OUTLET OF THE EVAPORATOR
S170
THE DEGREE OF SUPERHEAT AT THE OUTLET OF THE EVAPORATOR ≥ TARGET VALUE?
NO
YES
S180
CLOSE OIL REGULATING VALVE 64
S190
SHIFT TO THE HEATING OPERATION
RETURN
S200

FIG.13

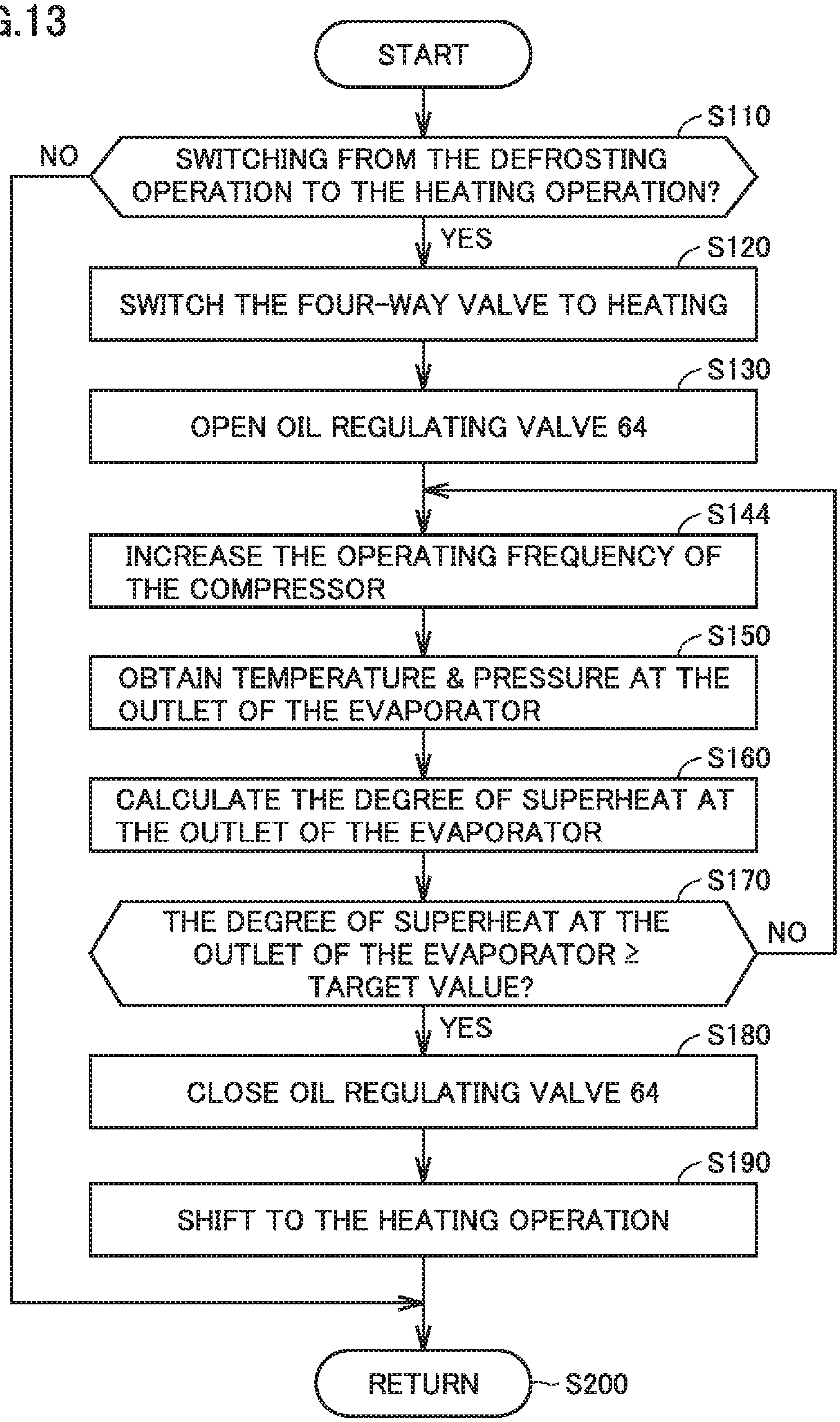

START
S110
SWITCHING FROM THE DEFROSTING OPERATION TO THE HEATING OPERATION?
NO
YES
S120
SWITCH THE FOUR-WAY VALVE TO HEATING
S130
OPEN OIL REGULATING VALVE 64
S144
INCREASE THE OPERATING FREQUENCY OF THE COMPRESSOR
S150
OBTAIN TEMPERATURE & PRESSURE AT THE OUTLET OF THE EVAPORATOR
S160
CALCULATE THE DEGREE OF SUPERHEAT AT THE OUTLET OF THE EVAPORATOR
S170
THE DEGREE OF SUPERHEAT AT THE OUTLET OF THE EVAPORATOR ≥ TARGET VALUE?
NO
YES
S180
CLOSE OIL REGULATING VALVE 64
S190
SHIFT TO THE HEATING OPERATION
RETURN
S200

FIG.14

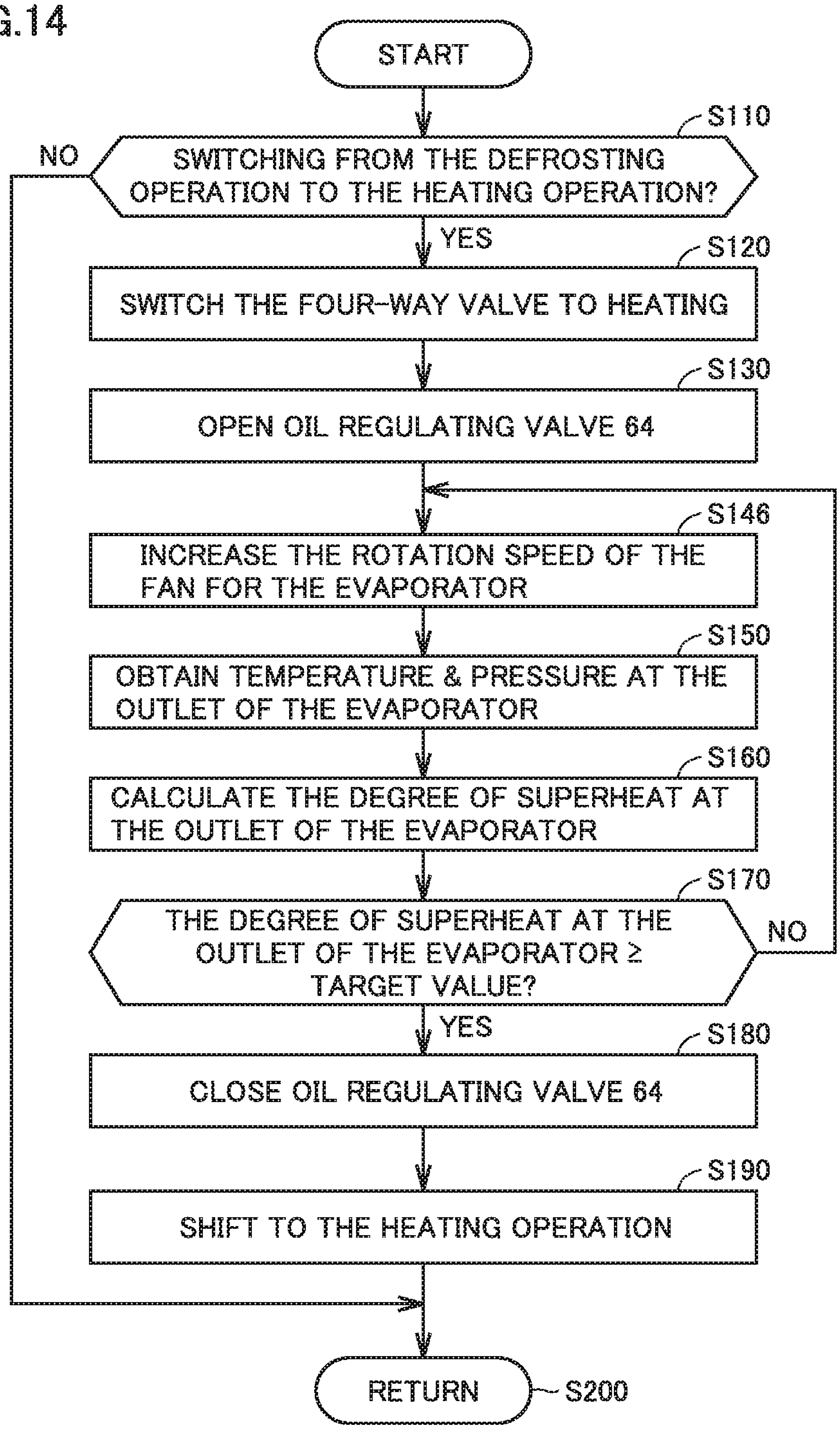

START
S110
SWITCHING FROM THE DEFROSTING OPERATION TO THE HEATING OPERATION?
NO
YES
S120
SWITCH THE FOUR-WAY VALVE TO HEATING
S130
OPEN OIL REGULATING VALVE 64
S146
INCREASE THE ROTATION SPEED OF THE FAN FOR THE EVAPORATOR
S150
OBTAIN TEMPERATURE & PRESSURE AT THE OUTLET OF THE EVAPORATOR
S160
CALCULATE THE DEGREE OF SUPERHEAT AT THE OUTLET OF THE EVAPORATOR
S170
THE DEGREE OF SUPERHEAT AT THE OUTLET OF THE EVAPORATOR ≥ TARGET VALUE?
NO
YES
S180
CLOSE OIL REGULATING VALVE 64
S190
SHIFT TO THE HEATING OPERATION
RETURN
S200

FIG.15

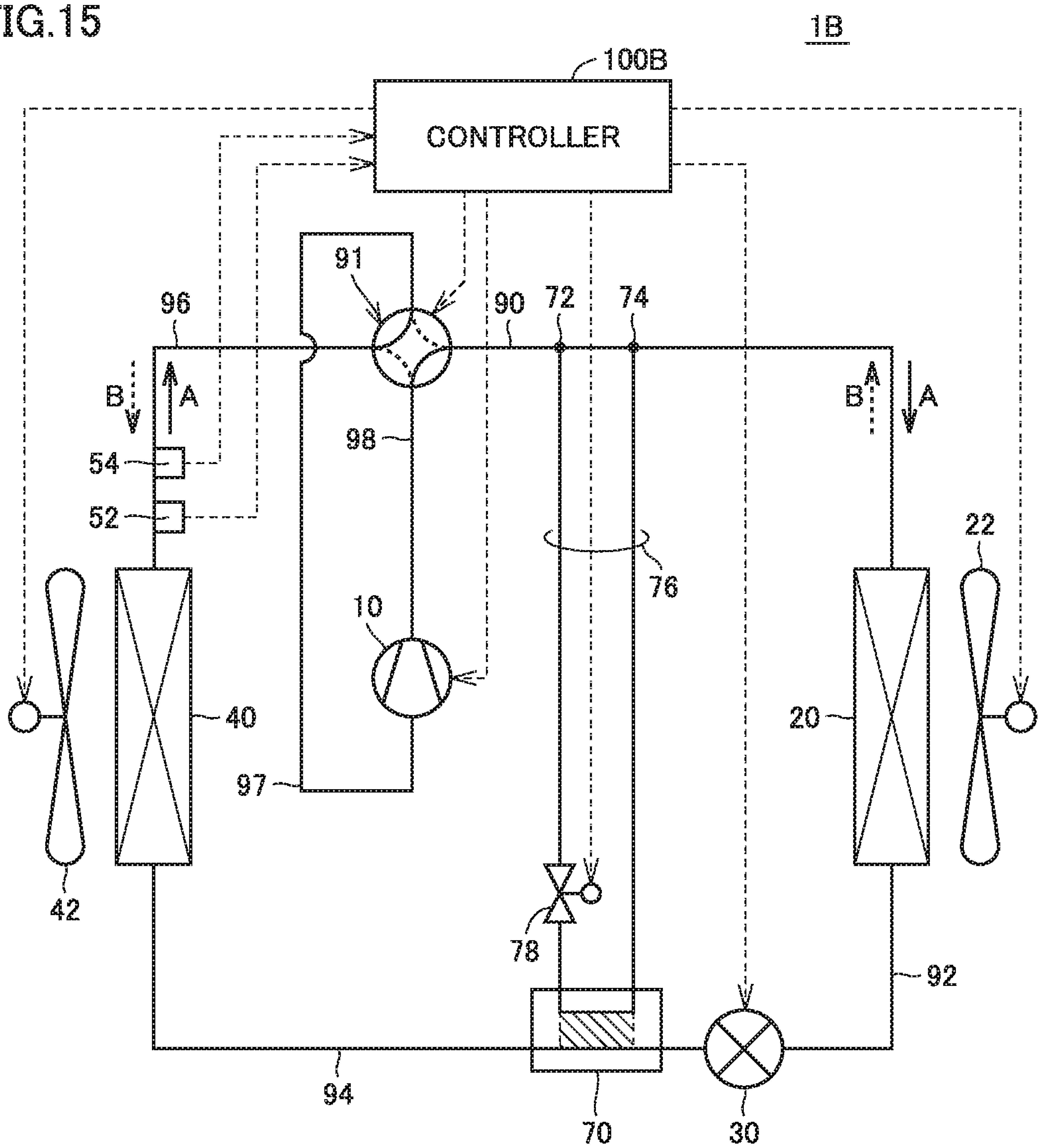

1B
100B
CONTROLLER
91
96
90
72
74
B
A
B
A
98
54
52
76
22
10
40
20
97
42
78
92
94
70
30

FIG.16

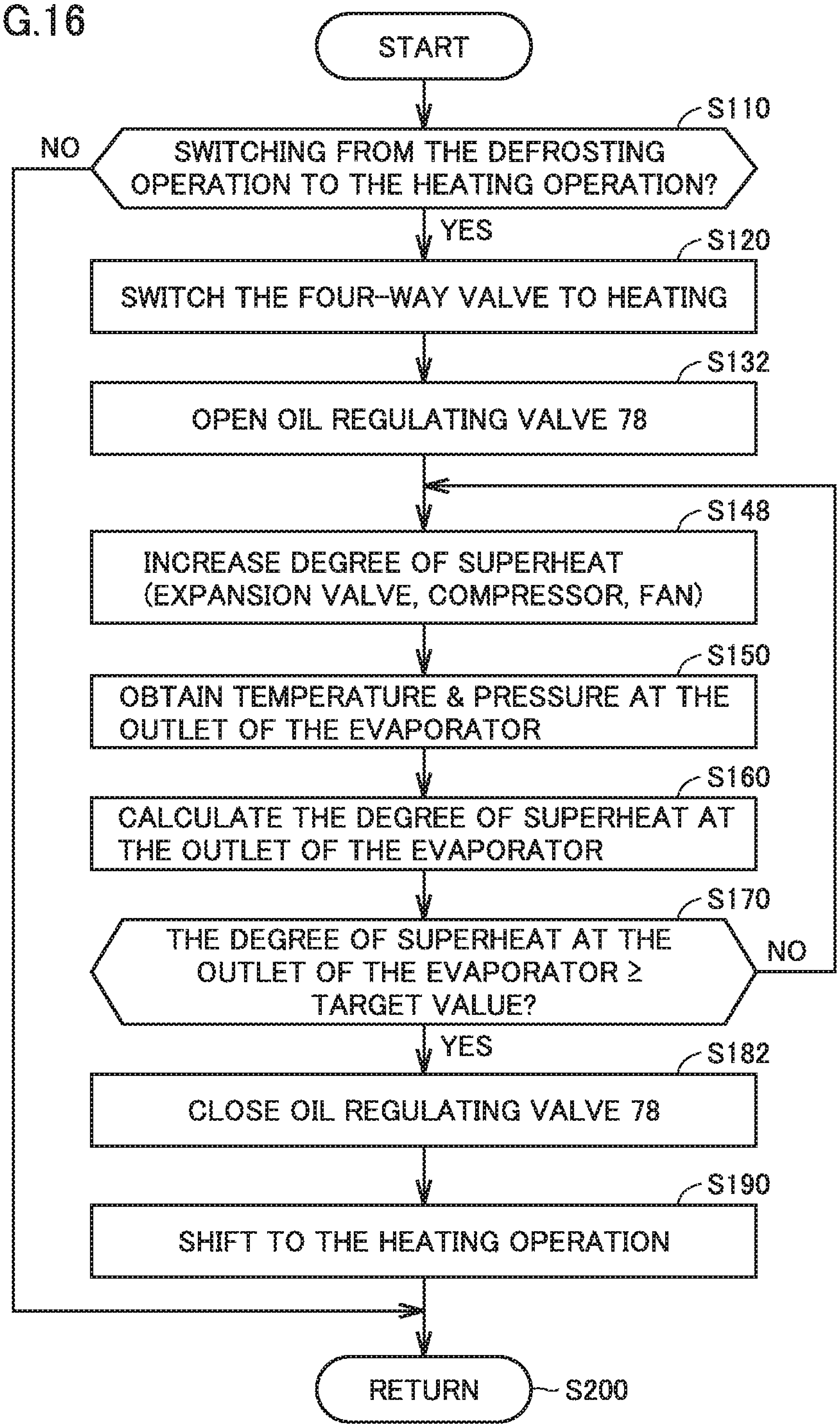

START
S110
SWITCHING FROM THE DEFROSTING OPERATION TO THE HEATING OPERATION?
NO
YES
S120
SWITCH THE FOUR-WAY VALVE TO HEATING
S132
OPEN OIL REGULATING VALVE 78
S148
INCREASE DEGREE OF SUPERHEAT (EXPANSION VALVE, COMPRESSOR, FAN)
S150
OBTAIN TEMPERATURE & PRESSURE AT THE OUTLET OF THE EVAPORATOR
S160
CALCULATE THE DEGREE OF SUPERHEAT AT THE OUTLET OF THE EVAPORATOR
S170
THE DEGREE OF SUPERHEAT AT THE OUTLET OF THE EVAPORATOR ≥ TARGET VALUE?
NO
YES
S182
CLOSE OIL REGULATING VALVE 78
S190
SHIFT TO THE HEATING OPERATION
RETURN
S200

FIG.17

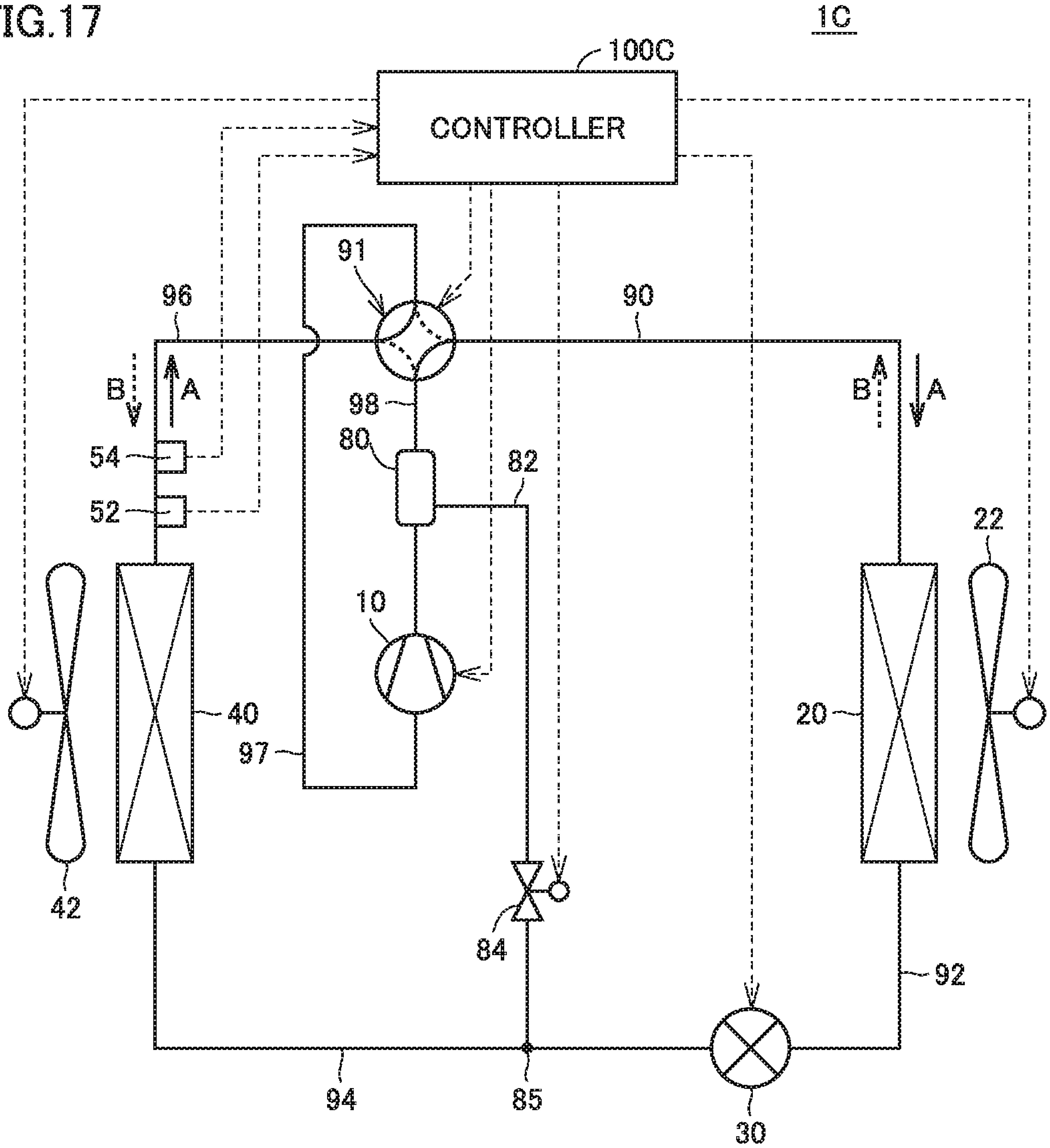

1C
100C
CONTROLLER
91
96
90
B
A
B
A
98
80
82
54
52
22
10
40
20
97
42
84
92
94
85
30

FIG.18

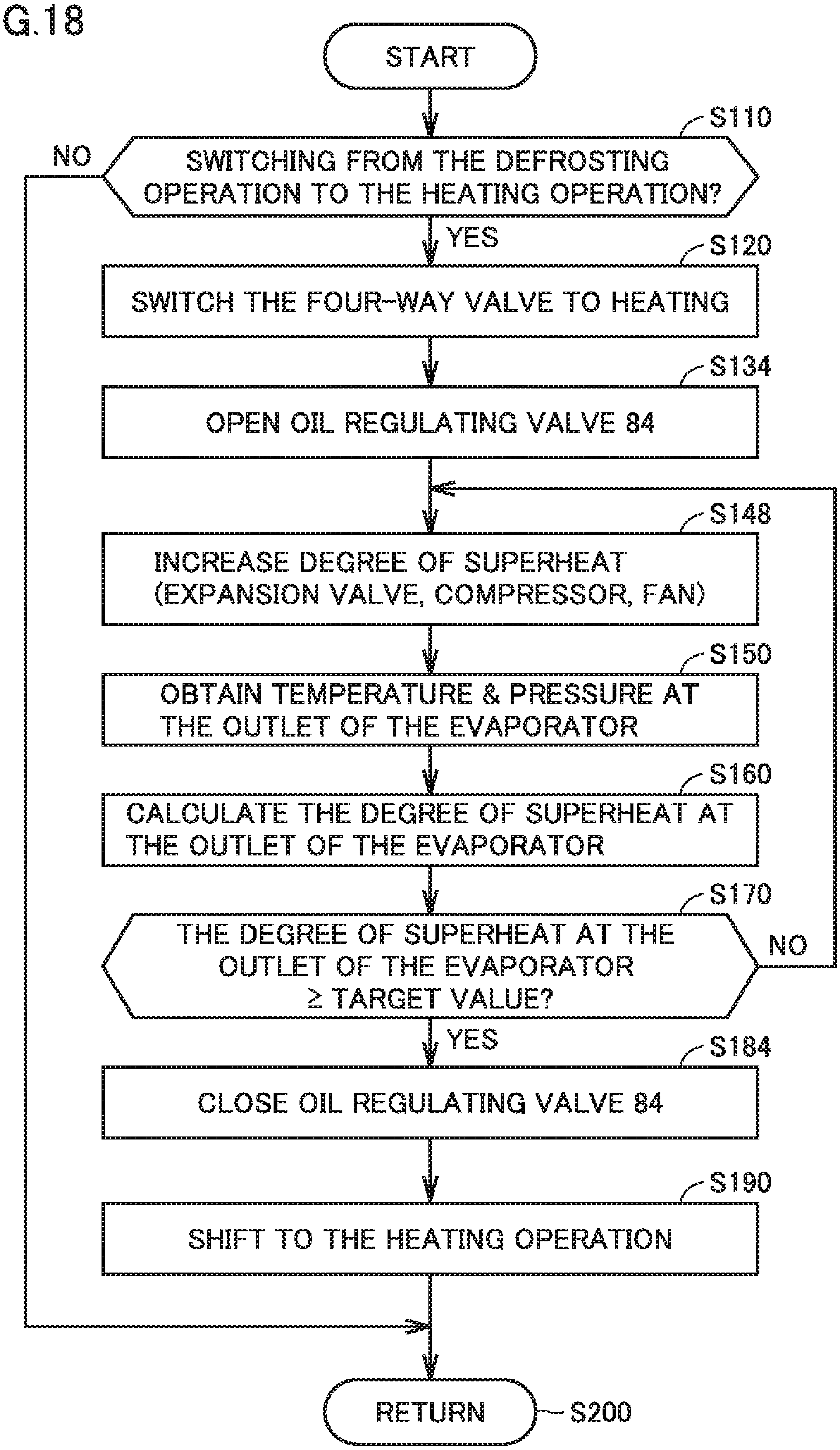
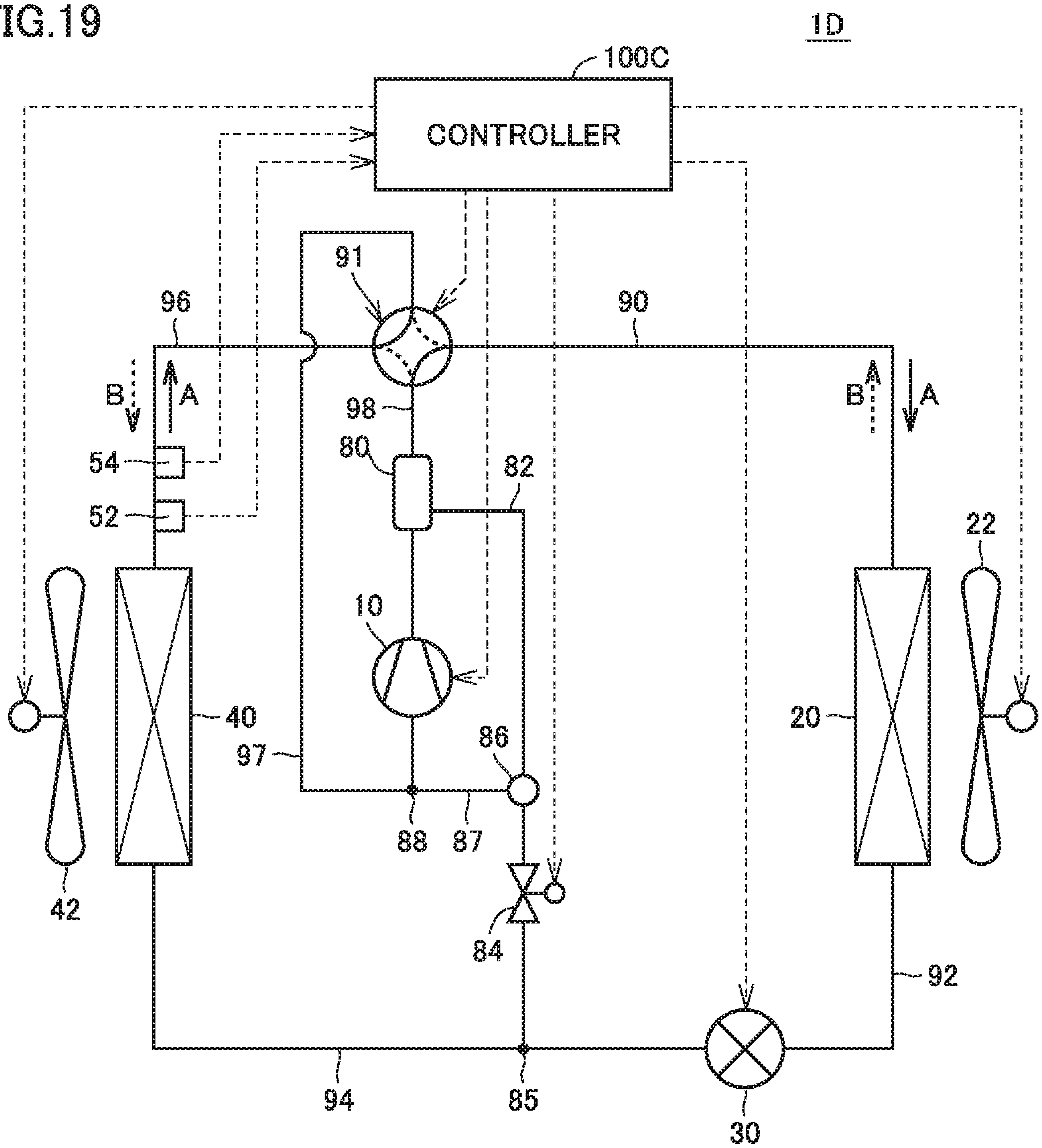

START
S110
SWITCHING FROM THE DEFROSTING OPERATION TO THE HEATING OPERATION?
NO
YES
S120
SWITCH THE FOUR-WAY VALVE TO HEATING
S134
OPEN OIL REGULATING VALVE 84
S148
INCREASE DEGREE OF SUPERHEAT (EXPANSION VALVE, COMPRESSOR, FAN)
S150
OBTAIN TEMPERATURE & PRESSURE AT THE OUTLET OF THE EVAPORATOR
S160
CALCULATE THE DEGREE OF SUPERHEAT AT THE OUTLET OF THE EVAPORATOR
S170
THE DEGREE OF SUPERHEAT AT THE OUTLET OF THE EVAPORATOR ≥ TARGET VALUE?
NO
YES
S184
CLOSE OIL REGULATING VALVE 84
S190
SHIFT TO THE HEATING OPERATION
RETURN
S200

FIG.19


1D
100C
CONTROLLER
91
96
90
B
A
B
A
98
80
82
54
52
22
10
40
20
97
86
88
87
42
84
92
94
85
30

REFRIGERATION CYCLE APPARATUS

CROSS REFERENCE TO RELATED APPLICATION

This application is a U.S. national stage application of PCT/JP2015/082788 filed on Nov. 20, 2015, the contents of which are incorporated herein by reference.

TECHNICAL FIELD

The present invention relates to a refrigeration cycle apparatus and a method of controlling the refrigeration cycle apparatus.

BACKGROUND ART

Japanese Patent Laying-Open No. 8-166183 (PTD 1) proposes an air conditioner which reduces a trouble of a compressor by preventing foaming from occulting in an accumulator as low-temperature and low-pressure refrigerant flows in when a defrosting operation ends. The air conditioner is provided with a bypass circuit connecting a pipe between a three-way valve and a four-way valve and a pipe between the four-way valve and an accumulator, and a solenoid valve provided to the bypass circuit.

In the air conditioner, the solenoid valve is opened to supply high-temperature and high-pressure refrigerant through the bypass circuit to the accumulator during a prescribed period of time from the start of the compressor or the end of the defrosting operation. This prevents foaming from occurring in the accumulator.

CITATION LIST

Patent Document

PTD 1: Japanese Patent Laying-Open No. 8-166183

SUMMARY OF INVENTION

Technical Problem

In a compressor, a lubricating oil (hereinafter also simply referred to as "oil") is present to ensure that the compressor has lubrication. While the compressor is stopped, refrigerant in the compressor is condensed into liquid refrigerant, and the liquid refrigerant dissolves into the oil in the compressor. Once an operation of the compressor is started, gaseous refrigerant is output from the compressor to a refrigerant circuit. Together with a flow of the gaseous refrigerant, a liquid mixture of the liquid refrigerant and the oil is taken out to the refrigerant circuit. Then, the oil taken out from the compressor to the refrigerant circuit as the liquid mixture circulates through the refrigerant circuit together with the refrigerant and returns to the compressor.

While the compressor is stopped, the refrigerant is condensed in the compressor into liquid refrigerant, as has been described above, and accordingly, the surface of the liquid (the oil and the liquid refrigerant) in the compressor is raised. When the operation of the compressor is started with the liquid surface raised, a large amount of the liquid mixture containing the oil is taken out from the compressor to the refrigerant circuit. Furthermore, while the compressor is stopped, the liquid refrigerant dissolves into the oil in the compressor, as has been described above, and accordingly, the liquid mixture in the compressor has a reduced oil

concentration. Accordingly, when the operation of the compressor is started, a large amount of the liquid mixture is taken out from the compressor to the refrigerant circuit and the compressor also has a reduced amount of oil therein, and thus there is a possibility that the compressor may suffer insufficient lubrication.

In the refrigeration apparatus described in PTD 1, the solenoid valve provided in the bypass circuit is opened to supply high-temperature and high-pressure refrigerant through the bypass circuit to the accumulator during a prescribed period of time from the start of the compressor. The liquid refrigerant is recovered in the accumulator, and the amount of the liquid mixture taken out from the compressor is also reduced, which is useful in terms of reducing the amount of the liquid refrigerant dissolved in the oil. However, the refrigeration apparatus described in PTD 1 requires a large-size accumulator and accordingly, the apparatus is increased in size and hence cost, which is a problem. Further, when the liquid refrigerant is dissolved in the oil in the compressor in a large amount, such as when the operation of the compressor is started, it is impossible to prevent the above-mentioned, possible insufficient lubrication, and a similar problem also arise when a heating operation is resumed after a defrosting operation.

The present invention has been made in view of such an issue, and an object of the present invention is to return a lubricating oil to a compressor in an increased amount to suppress insufficient lubrication of the compressor in a refrigeration cycle apparatus in which the oil circulates together with refrigerant.

Solution to Problem

According to the present invention, a refrigeration cycle apparatus comprises: a compressor configured to compress refrigerant; a first heat exchanger; a second heat exchanger; an expansion valve disposed in a refrigerant path interconnecting the first heat exchanger and the second heat exchanger; a four-way valve; and a controller. The four-way valve is configured to switch a direction of flow of the refrigerant between a first direction and a second direction, in the first direction the refrigerant output from the compressor being supplied to the first heat exchanger and the refrigerant being returned to the compressor from the second heat exchanger, in the second direction the refrigerant output from the compressor being supplied to the second heat exchanger and the refrigerant being returned to the compressor from the first heat exchanger. The controller is configured to control the four-way valve to switch an operation from a defrosting operation in which the refrigerant flows in the second direction to a heating operation in which the refrigerant flows in the first direction, to perform a heating preparation control for increasing a degree of superheat of the refrigerant returned to the compressor from the second heat exchanger, and thereafter to start the heating operation.

Advantageous Effects of Invention

In the refrigeration cycle apparatus according to the present invention, a control is performed to increase a degree of superheat of refrigerant output from a second heat exchanger (or an evaporator) to a compressor when a heating operation is started after a defrosting operation ends. This increases the region of a gas single phase in the second heat exchanger and increases oil concentration and oil viscosity in the second heat exchanger. When the oil viscosity in the second heat exchanger is increased, a liquid mixture of liquid refrigerant and oil taken out to the refrigerant circuit less easily flows in the second heat exchanger, and the amount of oil retained in the evaporator increases. Then, after the above control is performed, the heating operation is fully operated.

Thus, according to this refrigeration cycle apparatus, the oil retained in the second heat exchanger is supplied to the compressor when the heating operation is resumed after the defrosting operation ends, and the amount of oil returned to the compressor when the heating operation is resumed increases. As a result, a shortage of oil in the compressor that can occur when resuming the heating operation can be suppressed, and the compressor can be operated reliably.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** generally shows a configuration of a refrigeration cycle apparatus according to a first embodiment of the present invention.

FIG. **2** schematically shows a relationship between a liquid surface level in a compressor **10** and an amount of oil taken out from compressor **10** to a refrigerant circuit when compressor **10** is operated.

FIG. **3** represents a solubility of refrigerant into a lubricating oil in compressor **10**.

FIG. **4** represents a relationship between a degree of dryness (or quality) of a liquid with refrigerant mixed therein and a concentration of the oil in the liquid mixture.

FIG. **5** represents a relationship between a concentration of the oil and kinematic viscosity.

FIG. **6** is a timing plot representing a state of a four-way valve, an oil regulating valve, and the compressor as controlled when a heating operation is performed, stopped and resumed.

FIG. **7** is a flowchart of a procedure of a process performed for a period of time t1 to t2 in FIG. **6** (when stopping compressor **10**).

FIG. **8** is a flowchart of a procedure of a process performed by a controller **100** when stopping the compressor in a first exemplary variation.

FIG. **9** is a flowchart of a procedure of a process performed by controller **100** when stopping the compressor in a second exemplary variation.

FIG. **10** is a flowchart of a procedure of a process performed for a period of time t3 to t4 in FIG. **6** (when starting the operation of compressor **10**).

FIG. **11** is a timing plot representing a state of the four-way valve, the oil regulating valve, and the compressor as controlled when performing a defrosting operation and resuming the heating operation.

FIG. **12** is a flowchart of a procedure of a process performed by controller **100** as a preparation for the heating operation after the defrosting operation ends.

FIG. **13** is a flowchart of a procedure of a process performed by controller **100** when ending the defrosting operation in a first exemplary variation.

FIG. **14** is a flowchart of a procedure of a process performed by controller **100** when ending the defrosting operation in a second exemplary variation.

FIG. **15** generally shows a configuration of a refrigeration cycle apparatus according to a second embodiment of the present invention.

FIG. **16** is a flowchart of a procedure of a process performed by a controller **100**B in the second embodiment when resuming the heating operation after the defrosting operation.

FIG. **17** generally shows a configuration of a refrigeration cycle apparatus according to a third embodiment of the present invention.

FIG. **18** is a flowchart of a procedure of a process performed by a controller **100**C in a third embodiment when resuming the heating operation after the defrosting operation.

FIG. **19** generally shows a configuration of a refrigeration cycle apparatus **1**D according to a fourth embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

The present invention will now be described in embodiments hereinafter in detail with reference to the drawings. Hereinafter, while a plurality of embodiments will be described, the configurations described in the embodiments are intended to be combined together, as appropriate, in the present application as originally filed. In the figures, identical or corresponding components are identically denoted and will not be described redundantly.

First Embodiment

Configuration of Refrigeration Cycle Apparatus

FIG. **1** generally shows a configuration of a refrigeration cycle apparatus according to a first embodiment of the present invention. With reference to FIG. **1**, a refrigeration cycle apparatus **1** includes a compressor **10**, an indoor heat exchanger **20**, an indoor unit fan **22**, an expansion valve **30**, an outdoor heat exchanger **40**, an outdoor unit fan **42** , pipes **90**, **92**, **94**, **96**, a four-way valve **91**, a bypass pipe **62**, and an oil regulating valve **64**. Furthermore, refrigeration cycle apparatus **1** further includes a pressure sensor **52**, a temperature sensor **54**, and a controller **100**.

Pipe **90** interconnects four-way valve **91** and indoor heat exchanger **20**. Pipe **92** interconnects indoor heat exchanger **20** and expansion valve **30**. Pipe **94** interconnects expansion valve **30** and outdoor heat exchanger **40**. Pipe **96** interconnects outdoor heat exchanger **40** and four-way valve **91**. Compressor **10** has a discharge port and a suction port connected to four-way valve **91**.

Expansion valve **30** is disposed at a portion of a refrigerant path composed of pipes **92** and **94** interconnecting indoor heat exchanger **20** and outdoor heat exchanger **40**.

Compressor **10** is configured to be capable of changing its operating frequency in response to a control signal received from controller **100**. By changing the operating frequency of compressor **10**, an output of compressor **10** is adjusted. Compressor **10** can be of a variety of types, e.g., a rotary type, a reciprocating type, a scroll type, a screw type and the like.

In a heating operation, four-way valve **91** connects the discharge port of compressor **10** and pipe **90** and connects the suction port of compressor **10** and pipe **96** to pass refrigerant in a direction indicated by an arrow A indicated by a solid line. In a cooling operation or a defrosting operation, four-way valve **91** connects the discharge port of compressor **10** and pipe **96** and connects the suction port of compressor **10** and pipe **90** to pass the refrigerant in a direction indicated by an arrow B indicated by a broken line.

In other words, four-way valve **91** is configured to be capable of switching a direction in which the refrigerant flows between a first direction (for heating) and a second direction (for cooling/defrosting). The first direction (for heating) is a direction of fluid communication in which the refrigerant output from compressor **10** is supplied to indoor heat exchanger **20** and the refrigerant is returned to compressor **10** from outdoor heat exchanger **40**. The second direction (for cooling/defrosting) is a direction of fluid communication in which the refrigerant output from compressor **10** is supplied to outdoor heat exchanger **40** and the refrigerant is returned to compressor **10** from indoor heat exchanger **20**.

Bypass pipe **62** interconnects a branching portion **60** provided to a pipe connected to a discharging side of compressor **10** and a confluence portion **66** provided to pipe **94**. Oil regulating valve **64** is provided to bypass pipe **62** and is configured to be capable of adjusting its opening degree in response to a control signal received from controller **100**. It should be noted that oil regulating valve **64** may be a simple valve which only performs opening and closing operations.

Initially, a basic operation of the heating operation will be described. In the heating operation, refrigerant flows in the direction indicated by arrow A. Compressor **10** compresses the refrigerant drawn from pipe **96** via four-way valve **91**, and outputs the compressed refrigerant to pipe **90** via four-way valve **91**.

Indoor heat exchanger **20** (or a condenser) condenses the refrigerant output to pipe **90** from compressor **10** via four-way valve **91** and outputs the condensed refrigerant to pipe **92**. Indoor heat exchanger **20** (or the condenser) is configured to allow high-temperature and high-pressure superheated vapor (or the refrigerant) output from compressor **10** to exchange heat with indoor air (or radiate heat). By this heat exchange, the refrigerant is condensed and liquefied. Indoor unit fan **22** is adjacent to indoor heat exchanger **20** (or the condenser) and is configured to be capable of adjusting its rotation speed in response to a control signal received from controller **100**. By changing the rotation speed of indoor unit fan **22**, an amount of heat exchanged between the refrigerant in indoor heat exchanger **20** (or the condenser) and indoor air can be adjusted.

Expansion valve **30** decompresses the refrigerant output from indoor heat exchanger **20** (or the condenser) to pipe **92** and outputs the decompressed refrigerant to pipe **94**. Expansion valve **30** is configured to be capable of adjusting its opening degree in response to a control signal received from controller **100**. When the opening degree of expansion valve **30** is changed in a closing direction, the refrigerant on the output side of expansion valve **30** has a decreased pressure, and the refrigerant has an increased degree of dryness. On the other hand, when the opening degree of expansion valve **30** is changed in an opening direction, the refrigerant on the output side of expansion valve **30** has an increased pressure, and the refrigerant has a decreased degree of dryness.

Outdoor heat exchanger **40** (or an evaporator) evaporates the refrigerant output from expansion valve **30** to pipe **94** and outputs the evaporated refrigerant to pipe **96**. Outdoor heat exchanger **40** (or the evaporator) is configured to allow the refrigerant decompressed by expansion valve **30** to exchange heat with outdoor air (or absorb heat). By this heat exchange, the refrigerant evaporates and becomes superheated vapor. Outdoor unit fan **42** is adjacent to outdoor heat exchanger **40** (or the evaporator) and is configured to be capable of changing its rotation speed in response to a control signal received from controller **100**. By changing the rotation speed of outdoor unit fan **42**, an amount of heat exchanged between the refrigerant in outdoor heat exchanger **40** (or the evaporator) and outdoor air can be adjusted.

Pressure sensor **52** senses the pressure of the refrigerant at the outlet of outdoor heat exchanger **40** (or the evaporator) and outputs the sensed value to controller **100**. Temperature sensor **54** senses the temperature of the refrigerant at the outlet of outdoor heat exchanger **40** (or the evaporator) and outputs the sensed value to controller **100**.

Controller **100** includes a CPU (central processing unit), a storage device, an input/output buffer, and the like, none of which is shown, and controls each device in refrigeration cycle apparatus **1**. Note that this control is not limited to processing by software and can also be processed by dedicated hardware (or an electronic circuit).

Hereinafter, the cooling operation will be described. In the cooling operation, four-way valve **91** forms a path as indicated by the broken line, and the refrigerant flows in the direction indicated by arrow B. As a result, indoor heat exchanger **20** functions as an evaporator and outdoor heat exchanger **40** functions as a condenser, and accordingly, heat is absorbed indoor from indoor air and radiated outdoor to outdoor air.

Furthermore, a defrosting operation may be performed to melt frost adhering to outdoor heat exchanger **40** during a heating operation and this defrosting operation is also performed with four-way valve **91** set and the refrigerant passed in a direction similarly as done in the cooling operation.

Controller **100** applies control, based on a setting of cooling/heating, to switch four-way valve **91**, operate compressor **10** in response to an instruction to operate compressor **10**, and stop compressor **10** in response to an instruction to stop compressor **10**. Further, controller **100** controls the operating frequency of compressor **10**, the opening degree of expansion valve **30**, the rotation speed of indoor unit fan **22**, and the rotation speed of outdoor unit fan **42** to allow refrigeration cycle apparatus **1** to exhibit a desired performance.

Description of Phenomenon of Insufficiency of Lubricating Oil in the Compressor

In refrigeration cycle apparatus **1** having the above configuration, compressor **10** may be short of the lubricating oil when the heating operation is stopped, the heating operation is started, and the heating operation is resumed after the defrosting operation ends. Hereinafter, this matter will be described more specifically.

In compressor **10**, a lubricating oil is present to ensure that compressor **10** has lubrication. While compressor **10** is stopped, refrigerant in compressor **10** is condensed into liquid refrigerant, and the liquid refrigerant dissolves into the oil in compressor **10**. When an operation of compressor **10** is started, gaseous refrigerant is output from compressor **10** to a refrigerant circuit, and together with a flow of the gaseous refrigerant, a liquid mixture of the liquid refrigerant and the oil is taken out to the refrigerant circuit. The oil taken out from compressor **10** to the refrigerant circuit as the liquid mixture circulates through the refrigerant circuit together with the refrigerant and returns to compressor **10**.

While compressor **10** is stopped, the refrigerant is condensed in compressor **10** into liquid refrigerant, and accordingly, the surface of the liquid (the oil and the liquid refrigerant) in compressor **10** is raised. When the operation of compressor **10** is started with the liquid surface raised, a large amount of the liquid mixture containing the oil is taken out from compressor **10** to the refrigerant circuit.

FIG. **2** schematically shows a relationship between a liquid surface level in compressor **10** and an amount of oil taken out from compressor **10** to the refrigerant circuit when compressor **10** is operated. With reference to FIG. **2**, when the liquid surface in compressor **10** is raised, the amount of the oil (or the liquid mixture) taken out from compressor **10** to the refrigerant circuit when compressor **10** is operated increases. Although it depends on the type of compressor **10**, generally there exists an inflection point at which the amount of the oil taken out from compressor **10** rapidly increases when the liquid surface in compressor **10** exceeds a certain height H1. For example, when compressor **10** is of a rotary type, liquid surface level H1 corresponds to the lower end of a motor unit, and when the liquid surface of the liquid mixture in compressor **10** reaches the lower end of the motor unit, the amount of the oil taken out from compressor **10** to the refrigerant circuit rapidly increases.

FIG. **3** represents a solubility of the refrigerant into the lubricating oil in compressor **10**. Referring to FIG. **3**, the horizontal axis represents the solubility of the refrigerant into the oil and the vertical axis represents pressure. As indicated by the bottom graph of the three graphs, at low temperature, the refrigerant dissolves into the oil, even with low pressure applied. Accordingly, while compressor **10** is stopped, which is when temperature is lower than while compressor **10** is in operation, the amount of the refrigerant dissolved into the oil in compressor **10** increases, and as a result, the liquid mixture in compressor **10** has a decreased oil concentration.

Thus, while compressor **10** is stopped, the liquid mixture in compressor **10** has a raised liquid surface, and furthermore, also has a decreased oil concentration. Accordingly, when the operation of compressor **10** is started, a large amount of the liquid mixture is taken out from compressor **10** to the refrigerant circuit, and the liquid mixture in compressor **10** also has a decreased oil concentration, and compressor **10** may have insufficient lubrication. Such a phenomenon may also occur when resuming the heating operation after the defrosting operation ends.

Accordingly, in refrigeration cycle apparatus **1** according to the first embodiment, when there is a possibility of insufficient lubrication, a control is performed to increase a degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator).

Specifically, in the first embodiment, controller **100** performs a control to increase the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) by delivering the liquid mixture of the lubricating oil and the liquid refrigerant that is discharged from compressor **10** to outdoor heat exchanger **40** (or the evaporator) via the bypass circuit, changing the opening degree of expansion valve **30** in the closing direction, or the like.

When the opening degree of expansion valve **30** is changed in the closing direction, the pressure on the output side of expansion valve **30** decreases, and the refrigerant has an increased degree of dryness. This increases the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator). By increasing the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator), the amount of the oil retained in outdoor heat exchanger **40** (or the evaporator) can be increased. Hereinafter, this matter will be described more specifically.

FIG. **4** represents a relationship between a degree of dryness of a liquid with refrigerant mixed therein and a concentration of the oil in the liquid mixture. Referring to FIG. **4**, as the degree of dryness increases (or a gas single phase has an increased region relative to a liquid single phase), the liquid mixture has an increased oil concentration. FIG. **5** represents a relationship between oil concentration and kinematic viscosity. Referring to FIG. **5**, when the liquid mixture has a higher oil concentration, the graph shifts upward, and the liquid mixture has higher viscosity. Accordingly, from FIG. **4** and FIG. **5**, it is understood that as the degree of dryness is increased, the viscosity of the liquid mixture increases.

Accordingly, by increasing the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator), the degree of dryness in outdoor heat exchanger **40** (or the evaporator) and hence the oil concentration and oil viscosity in outdoor heat exchanger **40** (or the evaporator) can be increased. As the oil viscosity in outdoor heat exchanger **40** (or the evaporator) increases, the liquid mixture less easily flow in outdoor heat exchanger **40** (or the evaporator), and the amount of oil retained in outdoor heat exchanger **40** (or the evaporator) increases.

Controller **100** thus increases the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) to increase the amount of oil retained in outdoor heat exchanger **40** (or the evaporator). This increases an amount of oil returned to compressor **10** subsequently when compressor **10** is operated. As a result, shortage of oil in compressor **10** is reduced and compressor **10** operates reliably.

Description of Operation When Operation of Compressor is Stopped in Heating Operation

FIG. **6** is a timing plot representing states of the four-way valve, the oil regulating valve, and the compressor as controlled in a heating operation when the heating operation is stopped and resumed. FIG. **6** represents, from the top successively, states of four-way valve **91**, oil regulating valve **64**, and compressor **10** controlled. With reference to FIGS. **1** and **6**, while the heating operation is performed and stopped, four-way valve **91** is set to pass the refrigerant in the direction indicated by arrow A.

From time t0 a heating operation is performed and during the operation at time t1 an instruction is received from a user to stop the operation. In response, controller **100** performs an operation process for a period of time t1 to t2 with oil regulating valve **64** open and then stops the compressor at time t2.

After time t2 while the operation is stopped an instruction is received at time t3 from the user to start the operation. In response, controller **100** starts the operation of the compressor at time t3 and also performs a prescribed operation process for a period of time t3 to t4 with oil regulating valve **64** open. Then, at time t4, controller **100** closes oil regulating valve **64** and shifts to the heating operation.

The process performed by controller **100** for the period of time t1 to t2 shown in FIG. **6** and the process performed by controller **100** for the period of time t3 to t4 shown in FIG. **6** will be sequentially described.

FIG. **7** is a flowchart of a procedure of a process performed for the period of time t1 to t2 in FIG. **6** (when stopping compressor **10**). With reference to FIG. **1** and FIG. **7**, controller **100** determines whether there is an instruction received to stop compressor **10** (step S**10**). The instruction to stop compressor **10** may be generated by an operation done by the user of refrigeration cycle apparatus **1** to stop the apparatus or may be generated when a condition for stopping the apparatus is established. When controller **100** determines that there is no instruction to stop compressor **10** (NO in step S**10**), controller **100** shifts the process to step S**70** without performing the subsequent series of steps.

When controller **100** determines in step S**10** that there is an instruction received to stop compressor **10** (YES in step

S10), controller **100** opens oil regulating valve **64** (step S15). By opening oil regulating valve **64**, a portion of high-temperature and high-pressure refrigerant is directly supplied to the inlet portion of outdoor heat exchanger **40** (or the evaporator), which increases the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator).

Subsequently, controller **100** decreases the opening degree of expansion valve **30** (step S20). Specifically, controller **100** does not completely close expansion valve **30**; rather, controller **100** changes the opening degree of expansion valve **30** by a determined amount in the closing direction. This further increases the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator).

Subsequently, controller **100** obtains a value in temperature sensed at the outlet of outdoor heat exchanger **40** (or the evaporator) by temperature sensor **54** provided at the outlet of outdoor heat exchanger **40** (or the evaporator). Furthermore, controller **100** obtains a value in pressure sensed at the outlet of outdoor heat exchanger **40** (or the evaporator) by pressure sensor **52** provided at the outlet of outdoor heat exchanger **40** (or the evaporator) (step S**30**). Then, controller **100** calculates the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) from the values in pressure and temperature sensed at the outlet of outdoor heat exchanger **40** (or the evaporator) obtained in step S30 (Step S40). As described above, the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) is calculated by subtracting from the sensed temperature value a saturated gas temperature estimated from the sensed pressure value.

Subsequently, controller **100** determines whether the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) calculated in step S**40** is equal to or more than a target value (step S**50**). This target value can be set to a value allowing an increased degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) to ensure that a desired amount of oil is returned from outdoor heat exchanger **40** (or the evaporator) when the operation is started, and the target value can be determined in advance through an experiment or the like.

If controller **100** determines in step S**50** that the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) is lower than the target value (NO in step S**50**), controller **100** returns the process to step S**20** to further decrease the opening degree of expansion valve **30**. On the other hand, if controller **100** determines in step S**50** that the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) is equal to or larger than the target value (YES in step S**50**), controller **100** stops compressor **10** (step S**60**).

Referring again to FIG. **1**, how the refrigerant and the oil (or the liquid mixture) flow as controller **100** operates as described above will be described below. For the sake of comparison, how the refrigerant and the oil flow in a normal operation (i.e., an operation which is not performed immediately before an operation is stopped or immediately after an operation is started) will initially be described.

In a normal heating operation, high-temperature and high-pressure gaseous refrigerant (or superheated vapor) and together therewith a liquid mixture of liquid refrigerant and oil are output from compressor **10** to pipe **90**, as indicated by arrow A. The gaseous refrigerant and liquid mixture flowing from pipe **90** into indoor heat exchanger **20** (or the condenser) exchange heat with indoor air in indoor heat exchanger **20** (or the condenser) (or radiate heat). In indoor heat exchanger **20** (or the condenser), the refrigerant is decreased in degree of dryness and thus condensed and liquefied. As the refrigerant is further liquefied, the liquid mixture has a decreased oil concentration. The refrigerant and liquid mixture output from indoor heat exchanger **20** (or the condenser) to pipe **92** are decompressed by expansion valve **30** (i.e., undergo isenthalpic expansion).

Expansion valve **30** outputs low-temperature and low-pressure gaseous refrigerant and a low-oil-concentration liquid mixture which are in turn flow through pipe **94** into outdoor heat exchanger **40** (or the evaporator). The gaseous refrigerant and liquid mixture flowing into outdoor heat exchanger **40** (or the evaporator) exchange heat with outdoor air in outdoor heat exchanger **40** (or the evaporator) (or absorb heat). In outdoor heat exchanger **40** (or the evaporator), the refrigerant is increased in degree of dryness and thus becomes superheated vapor. As the refrigerant is further evaporated, the liquid mixture has an increased oil concentration. The gaseous refrigerant and liquid mixture output from outdoor heat exchanger **40** (or the evaporator) flow into compressor **10** through pipe **96** and the liquid mixture containing the oil returns to compressor **10**.

Controller **100** calculates the degree of superheat at the outlet of outdoor heat exchanger **40** based on the respective sensed values of pressure sensor **52** and temperature sensor **54** provided at the outlet of outdoor heat exchanger **40**. Specifically, controller **100** uses a pressure-temperature map or the like indicating a relationship between the refrigerant's saturation pressure and the saturated gas temperature to estimate a saturated gas temperature Tg from the pressure sensed by pressure sensor **52** at the outlet of outdoor heat exchanger **40**. Controller **100** calculates the degree of superheat at the outlet of outdoor heat exchanger **40** by subtracting saturated gas temperature Tg from a temperature Teo sensed by temperature sensor **54** at the outlet of outdoor heat exchanger **40**.

Subsequently, when stopping compressor **10**, controller **100** performs a control to increase the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator).

Specifically, when an instruction to stop compressor **10** is issued, and compressor **10** stops, controller **100** controls oil regulating valve **64** to change the state from a closed state to an open state. In response, the high-temperature and high-pressure gaseous refrigerant and high-oil-concentration liquid mixture output from compressor **10** are partially supplied from branching portion **60** of pipe **90** through bypass pipe **62** to confluence portion **66** of pipe **94**, interflow with the low-temperature and low-pressure gaseous refrigerant and low-oil-concentration liquid mixture output from expansion valve **30** and are thus supplied to outdoor heat exchanger **40** (or the evaporator). Thus, the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) increases, and the high-oil-concentration liquid mixture taken out from compressor **10** is partially supplied to outdoor heat exchanger **40** (or the evaporator).

Further, in order to increase the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator), controller **100** decreases the opening degree of expansion valve **30**. This increases the degree of dryness within outdoor heat exchanger **40** (or the evaporator) and hence the region of the gas single phase. The liquid mixture in outdoor heat exchanger **40** (or the evaporator) is increased in oil concentration and hence oil viscosity. As the liquid mixture in outdoor heat exchanger **40** (or the evaporator) has an increased oil viscosity, the liquid mixture less easily flow in outdoor heat exchanger **40** (or the evaporator), and the amount of oil retained in outdoor heat exchanger **40** (or the evaporator) increases. When it is determined that the outlet of outdoor heat exchanger **40** (or the evaporator) has a degree of superheat equal to or greater than a target value and accordingly, it is determined that outdoor heat exchanger **40** (or the evaporator) sufficiently retains the oil therein, compressor **10** stops.

Thus, when stopping compressor **10**, oil regulating valve **64** assuming the closed position is controlled to assume an open position and the opening degree of expansion valve **30** is also changed in the closing direction to increase the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator). This increases the amount of oil retained in outdoor heat exchanger **40** (or the evaporator), and thereafter, compressor **10** stops. Thus, according to the control shown in FIG. **7**, the amount of oil returned to compressor **10** can be increased when starting the operation of compressor **10**. As a result, a shortage of oil in compressor **10** that can occur when starting the operation of the compressor can be suppressed, and the compressor can be operated reliably.

First Exemplary Variation When Stopping the Compressor

In the above control, when stopping compressor **10**, the opening degree of expansion valve **30** is changed in the closing direction to increase the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator). Alternatively, the operating frequency of compressor **10** may be increased in order to increase the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator). When the operating frequency of compressor **10** is increased, the flow rate of the refrigerant flowing through the refrigerant circuit increases, and the amount of heat to be processed by outdoor heat exchanger **40** (or the evaporator) and indoor heat exchanger **20** (or the condenser) increases. Accordingly, the evaporation temperature of the refrigerant in outdoor heat exchanger **40** (or the evaporator) decreases and the condensation temperature of the refrigerant in indoor heat exchanger **20** (or the condenser) increases.

As a result, the amount of the refrigerant shifts in the refrigerant circuit toward indoor heat exchanger **20** (or the condenser) as compared with that before the operating frequency of compressor **10** is increased, and the degree of dryness increases on the side of outdoor heat exchanger **40** (or the evaporator), whereby the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) increases.

FIG. **8** is a flowchart of a procedure of a process performed by controller **100** when stopping the compressor in a first exemplary variation. Referring to FIG. **8**, this flowchart corresponds to the flowchart shown in FIG. **7** with step S**20** replaced with step S**21**.

More specifically, when controller **100** determines in step S**10** that there is an instruction received to stop compressor **10** (YES in step S**10**), controller **100** opens oil regulating valve **64** (step S**15**) and subsequently, increases the operating frequency of compressor **10** (step S**21**). Specifically, controller **100** changes the operating frequency of compressor **10** by a determined amount in a direction allowing the operating frequency of compressor **10** to be increased. This increases the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator). After step S**21** is performed, controller **100** shifts the process to step S**30**. Note that the steps other than step S**21** are identical to those of the flowchart shown in FIG. **7**.

Second Exemplary Variation When Stopping the Compressor

In the first exemplary variation, the operating frequency of compressor **10** is increased in order to increase the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator). Alternatively, the rotation speed of outdoor unit fan **42** may be increased. Outdoor unit fan **42** rotating faster helps the refrigerant and liquid mixture in outdoor heat exchanger **40** (or the evaporator) to exchange heat with outdoor air (or absorb heat). This results in an increased degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator).

FIG. **9** is a flowchart of a procedure of a process performed by controller **100** when stopping the compressor in the second exemplary variation. Referring to FIG. **9**, this flowchart corresponds to the flowchart shown in FIG. **7** according to the first embodiment with step S**20** replaced with step S**22**.

More specifically, when controller **100** determines in step S**10** that there is an instruction received to stop compressor **10** (YES in step S**10**), controller **100** opens oil regulating valve **64** (step S**15**) and subsequently, increases the rotation speed of outdoor unit fan **42** (step S**22**). Specifically, controller **100** changes the rotation speed of outdoor unit fan **42** by a determined amount in a direction allowing the rotation speed of outdoor unit fan **42** to be increased. This increases the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator). After step S**22** is performed, controller **100** shifts the process to step S**30**. Note that the steps other than step S**22** are identical to those of the flowchart shown in FIG. **7**.

Description of Operation When Starting Operation of Compressor When Performing Heating Operation

In FIGS. **7**-**9**, when stopping compressor **10**, a control is performed for increasing the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator). However, the control for increasing the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) is performed not only when stopping compressor **10** but preferably also performed when starting the operation of compressor **10**. This suppresses liquid back to compressor **10** when starting the operation of compressor **10**. Note that "liquid back" means that liquefied refrigerant (or liquid refrigerant) flows into compressor **10**.

More specifically, when liquid back to compressor **10** occurs when starting the operation of compressor **10**, compressor **10** may operate unsatisfactorily. Furthermore, when liquid back to compressor **10** occurs, the liquid surface in compressor **10** is raised, and the oil concentration in compressor **10** decreases. Furthermore, when liquid back occurs, the amount of the liquid mixture delivered from compressor **10** would also increase, and as a result, the amount of the lubricating oil taken out from compressor **10** would also increase. Accordingly, when liquid back occurs when starting the operation of compressor **10**, the possibility that compressor **10** has insufficient lubrication, as has been described above in the first embodiment, is further increased.

Refrigeration cycle apparatus **1** performs control to increase the degree of superheat at the outlet of outdoor heat exchanger **40** when stopping compressor **10** (see FIG. **6**, time period t1 to t2) (see FIGS. **7** to **9**), and in addition, refrigeration cycle apparatus **1** also performs control to increase the degree of superheat at the outlet of outdoor heat exchanger **40** when starting the operation of compressor **10** (see FIG. **6**, time period t3 to t4). This increases the degree of superheat at the inlet of compressor **10** and suppresses liquid hack to compressor **10** when the operation of compressor **10** starts.

FIG. **10** is a flowchart of a procedure of a process performed for period of time t3 to t4 in FIG. **6** (when compressor **10** starts operation). With reference to FIG. **1** and FIG. **10**, controller **100** determines whether the operation of compressor **10** is started (step S**110**). When controller **100** determines that the operation of compressor **10** is not started (NO in step S**110**), controller **100** shifts the process to step S**170** without performing the subsequent series of steps.

When controller **100** determines in step S**110** that the operation of compressor **10** is started (YES in step S**110**), controller **100** opens oil regulating valve **64** (step S**115**) and subsequently performs control to increase the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) (step S**120**). Specifically, controller **100** may decrease the opening degree of expansion valve **30** (see step S**20** in FIG. **7**) or may increase the operating frequency of compressor **10** (see step S**21** in FIG. **8**) or may increase the rotation speed of outdoor unit tan **42** (see step S**22** in FIG. **9**).

Subsequently, controller **100** obtains a value in temperature sensed at the outlet of outdoor heat exchanger **40** (or the evaporator) by temperature sensor **54** provided at the outlet of outdoor heat exchanger **40** (or the evaporator). Furthermore, controller **100** obtains a value in pressure sensed at the outlet of outdoor heat exchanger **40** (or the evaporator) by pressure sensor **52** provided at the outlet of outdoor heat exchanger **40** (or the evaporator) (step S**130**). Then, controller **100** calculates the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) from the values in pressure and temperature sensed at the outlet of outdoor heat exchanger **40** (or the evaporator) obtained in step S**130** (Step S**140**). Furthermore, controller **100** determines whether the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) calculated in step S**140** is equal to or more than a target value (step S**150**). Steps S**130** to S**150** are identical to steps S**30** to S**50**, respectively, shown in FIG. **7**.

If controller **100** determines in step S**150** that the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) is lower than the target value (NO in step S**150**), controller **100** returns the process to step S**120** and further performs a control to increase the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator). On the other hand, if controller **100** determines in step S**150** that the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) is equal to or larger than the target value (YES in step S**150**), controller **100** ends the control for increasing the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) (step S**160**) and subsequently closes oil regulating valve **64** (Step S**165**).

Thus the control for increasing the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) is performed not only when stopping compressor **10** but also performed when starting the operation of compressor **10**. Liquid back to compressor **10** when starting the operation of compressor **10** can thus be suppressed.

Thereafter when the operation of compressor **10** is started, a liquid mixture having a low oil concentration is taken out to the refrigerant circuit together with gaseous refrigerant. As a result, the liquid surface in compressor **10** is lowered, and as the liquid surface is lowered, the amount of the liquid mixture taken out to the refrigerant circuit is also decreased. Meanwhile, the liquid mixture retained in outdoor heat exchanger **40** (or the evaporator) and having a high oil concentration flows into compressor **10** (i.e., the amount of oil returned to compressor **10** is increased). As the amount of the liquid mixture taken out decreases and the liquid mixture having a high oil concentration flows into compressor **10**, the oil concentration in compressor **10** increases. This reduces shortage of oil in compressor **10** and allows compressor **10** to operate reliably.

Description of Operation When Performing Defrosting Operation and Resuming Heating Operation

Referring again to FIG. **1**, controller **100** controls four-way valve **91** to switch an operation from a defrosting operation to a heating operation and also performs a heating preparation control to increase the degree of superheat of the refrigerant output to compressor **10** from outdoor heat exchanger **40**, and thereafter starts the heating operation.

Refrigeration cycle apparatus **1** further includes pipe **98** for supplying four-way valve **91** with the refrigerant output from compressor **10**, pipe **94** for supplying outdoor heat exchanger **40** with the refrigerant output from expansion valve **30** in the heating operation, bypass pipe **62** interconnecting pipe **98** and pipe **94**, and oil regulating valve **64** provided to bypass pipe **62**. In the heating preparation control, controller **100** performs control to open oil regulating valve **64** assuming the closed position.

FIG. **11** is a timing plot representing a state of the four-way valve, the oil regulating valve, and the compressor as controlled when performing the defrosting operation and resuming the heating operation. FIG. **11** represents, from the top successively, states of four-way valve **91**, oil regulating valve **64**, and compressor **10** controlled. With reference to FIGS. **1** and **11**, while the heating operation is performed, four-way valve **91** is set to pass the refrigerant in the direction indicated by arrow A.

From time t10 a heating operation is performed and during the heating operation at time t11 outdoor heat exchanger **40** is frosted and a condition for starting the defrosting operation is established, and in response the defrosting operation starts.

For a period of time t11 to t12 the defrosting operation is performed with four-way valve **91** switched to pass the refrigerant in direction B. Furthermore, oil regulating valve **64** is closed as in the heating operation.

At time t12, the defrosting operation ends as a condition for ending the defrosting operation is established, e.g., a prescribed period of time elapses, the temperature of the outdoor heat exchanger is increased, or the like.

For a period of time t12 to t13, a heating preparation operation is performed for resuming a heating operation to be performed after time t13. At time t12, four-way valve **91** is switched to change a direction in which the refrigerant is passed from the direction indicated by arrow B to the direction indicated by arrow A. Simultaneously, oil regulating valve **64** assuming the closed position is opened.

For period of time t12 to t13 or in the heating preparatory operation the lubricating oil is retained in outdoor heat exchanger **40**, and thereafter at time t13 oil regulating valve **64** is closed and the operation is shifted to the heating operation.

The process performed by controller **100** for period of time t12 to t13 shown in FIG. **11** will be described hereinafter. At time t12, or when the defrosting operation ends, oil regulating valve **64** is opened to allow the liquid mixture taken out from compressor **10** to be supplied through bypass pipe **62** to the inlet of outdoor heat exchanger **40** (or the evaporator), and accordingly, the amount of oil returned to compressor **10** when the operation of compressor **10** is started is increased. Further, as high-temperature and high-pressure refrigerant flows from confluence portion **66** into outdoor heat exchanger **40** (or the evaporator), the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) accordingly increases and the degree of superheat at the suction port of compressor **10** also increases, and liquid back to compressor **10** is suppressed.

Thus, by opening oil regulating valve **64** after the defrosting operation ends, liquid back to compressor **10** is suppressed, and an amount of oil returned to compressor **10** is also ensured.

FIG. **12** is a flowchart of a procedure of a process performed by controller **100** as a preparation for the heating operation after the defrosting operation ends. The process of this flowchart is invoked from a main routine whenever a prescribed period of time elapses or a prescribed condition is established.

With reference to FIGS. **1** and **12**, while a condition for switching from the defrosting operation to the heating operation is unestablished in step **S110** (NO in step **S110**), controller **100** proceeds from step **S110** to step **S200** and returns to the main routine.

When controller **100** determines in step **S110** that the condition for switching from the defrosting operation to the heating operation is established (YES in step **S110**), controller **100** switches four-way valve **91** to change a direction in which the refrigerant is passed from the direction indicated by arrow B to the direction indicated by arrow A (step **S120**). Subsequently, controller **100** opens oil regulating valve **64** provided at bypass pipe **62** and currently assuming the closed position (step **S130**). By opening oil regulating valve **64**, a portion of high-temperature and high-pressure refrigerant is directly supplied to the inlet portion of outdoor heat exchanger **40** (or the evaporator), which increases the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator).

This facilitates evaporation of the liquid refrigerant and suppresses liquid back to compressor **10**, and also increases the amount of oil returned to compressor **10**. After step **S130** is performed, controller **100** decreases the opening degree of the expansion valve (step **S142**). Specifically, controller **100** does not completely close expansion valve **30**; rather, controller **100** changes the opening degree of expansion valve **30** by a determined amount in the closing direction. This further increases the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator).

Subsequently, controller **100** obtains a value in temperature sensed at the outlet of outdoor heat exchanger **40** (or the evaporator) by temperature sensor **54** provided at the outlet of outdoor heat exchanger **40** (or the evaporator). Furthermore, controller **100** obtains a value in pressure sensed at the outlet of outdoor heat exchanger **40** (or the evaporator) by pressure sensor **52** provided at the outlet of outdoor heat exchanger **40** (or the evaporator) (step **S150**). Then, controller **100** calculates the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) from the values in pressure and temperature sensed at the outlet of outdoor heat exchanger **40** (or the evaporator) obtained in step **S150** (Step **S160**). As has been previously described, the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) is calculated by subtracting from the sensed temperature value a saturated gas temperature estimated from the sensed pressure value.

Subsequently, controller **100** determines whether the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) calculated in step **S150** is equal to or more than a target value (step **S170**). This target value can be set to a value allowing an increased degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) to ensure that a desired amount of oil is returned from outdoor heat exchanger **40** (or the evaporator) when the operation is started, and the target value can be determined in advance through an experiment or the like.

If controller **100** determines in step **S170** that the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) is lower than the target value (NO in step **S170**), controller **100** returns the process to step **S42** to further decrease the opening degree of expansion valve **30**. On the other hand, if controller **100** determines in step **S170** that the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) is equal to or larger than the target value (YES in step **S170**), controller **100** closes oil regulating valve **64** (step **S180**) and subsequently shifts to the heating operation (step **S190**).

Thus a control similar to those applied when stopping the compressor in the first and second exemplary variations can also be performed when ending the defrosting operation as described above. These exemplary variations will be described hereinafter.

First Exemplary Variation When Ending the Defrosting Operation

FIG. **13** is a flowchart of a procedure of a process performed by controller **100** when ending the defrosting operation in a first exemplary variation. Referring to FIG. **13**, this flowchart corresponds to the flowchart shown in FIG. **12** with step **S142** replaced with step **S144**.

More specifically, when controller **100** determines in step **S110** that a command is received to switch from the defrosting operation to the heating operation (YES in step **S110**), controller **100** switches four-way valve **91** to heating and thereafter opens oil regulating valve **64** (steps **S120** and **S130**), and subsequently increases the operating frequency of compressor **10** (step **S144**). Specifically, controller **100** changes the operating frequency of compressor **10** by a determined amount in a direction allowing the operating frequency of compressor **10** to be increased. This increases the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator). After step **S144** is performed, controller **100** shifts the process to step **S150**. Note that the steps other than step **S144** are identical to those of the flowchart shown in FIG. **12**.

Second Exemplary Variation When Ending the Defrosting Operation

In the first exemplary variation, the operating frequency of compressor **10** is increased in order to increase the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator). Alternatively, the rotation speed of outdoor unit fan **42** may be increased. Outdoor unit fan **42** rotating faster helps the refrigerant and liquid mixture in outdoor heat exchanger **40** (or the evaporator) to exchange heat with outdoor air (or absorb heat). This results in an increased degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator).

FIG. **14** is a flowchart of a procedure of a process performed by controller **100** when ending the defrosting operation in a second exemplary variation. Referring to FIG.

14, this flowchart corresponds to the flowchart shown in FIG. **12** with step S**142** replaced with step S**146**.

More specifically, when controller **100** determines in step S**110** that a command is received to switch from the defrosting operation to the heating operation (YES in step S**110**), controller **100** switches four-way valve **91** to heating and thereafter opens oil regulating valve **64** (steps S**120** and S**130**), and subsequently increases the rotation speed of outdoor unit fan **42** (step S**146**). Specifically, controller **100** changes the rotation speed of outdoor unit fan **42** by a determined amount in a direction allowing the rotation speed of outdoor unit fan **42** to be increased. This increases the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator). After step S**146** is performed, controller **100** shifts the process to step S**150**. Note that the steps other than step S**146** are identical to those of the flowchart shown in FIG. **12**.

As described above, in the present embodiment, when stopping compressor **10** in stopping the heating operation, as shown in the timing plot in FIG. **6**, when starting the operation of compressor **10** in starting the heating operation, as shown in the timing plot in FIG. **6**, and when resuming the heating operation after the defrosting operation ends, as shown in FIG. **11**, the lubricating oil is collected to outdoor heat exchanger **40** while liquid back is prevented to prevent the compressor from suffering shortage of the lubricating oil when starting or resuming the heating operation.

Note that the process of each flowchart may not be performed in all of stopping compressor **10**, starting the operation of compressor **10**, and resuming the heating operation after the defrosting operation ends, and at least one of the processes of FIGS. **7-10** may be performed and thereby a similar effect can be obtained to some extent.

Second Embodiment

In a second embodiment, refrigeration cycle apparatus **1** is configured to allow the high-temperature and high-pressure gaseous refrigerant and liquid mixture output from compressor **10** and the low-temperature and low-pressure gaseous refrigerant and liquid mixture output from expansion valve **30** to mutually exchange heat when the refrigerant flows in the direction indicated by arrow A. This increases the degree of dryness of the gaseous refrigerant and liquid mixture flowing into outdoor heat exchanger **40** (or the evaporator), and increases the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator). As a result, the lubricating oil can be retained in outdoor heat exchanger **40** (or the evaporator) when stopping and starting the operation of compressor **10** and when resuming the heating operation after the defrosting operation ends, and the amount of oil returned to compressor **10** can be increased when starting the operation of compressor **10**.

FIG. **15** generally shows a configuration of a refrigeration cycle apparatus according to the second embodiment. Referring to FIG. **15**, this refrigeration cycle apparatus **1**B has the configuration of refrigeration cycle apparatus **1** shown in FIG. **1** according to the first embodiment with bypass pipe **62**, oil regulating valve **64**, and controller **100** replaced with an internal heat exchanger **70**, a branch pipe **76**, an oil regulating valve **78**, and a controller **100**B.

Internal heat exchanger **70** is configured to operate in the heating operation to allow the refrigerant output from compressor **10** and the refrigerant output from expansion valve **30** to exchange heat. Branch pipe **76** in the heating operation branches off the refrigerant supplied from compressor **10** to indoor heat exchanger **20** and supplies the branched refrigerant to internal heat exchanger **70**. Oil regulating valve **78** is provided to branch pipe **76**. Controller **100**B in the heating preparation control performs control to open oil regulating valve **78** assuming the closed position.

Internal heat exchanger **70** is configured allow the high-temperature and high-pressure gaseous refrigerant and liquid mixture output from compressor **10** and the low-temperature and low-pressure gaseous refrigerant and liquid mixture output from expansion valve **30** to mutually exchange heat when the refrigerant flows in the direction indicated by arrow A. In the second embodiment, as an example, internal heat exchanger **70** is provided at pipe **94** and allows the high-temperature and high-pressure gaseous refrigerant and liquid mixture flowing through branch pipe **76** branched from pipe **90** and the low-temperature and low-pressure gaseous refrigerant and liquid mixture flowing, through pipe **94** to exchange heat.

Branch pipe **76** is configured to branch from pipe **90** at a branching portion **72** and be connected via internal heat exchanger **70** to pipe **90** at a confluence portion **74**, which is provided closer to indoor heat exchanger **20** than branching portion **72**. Oil regulating valve **78** is provided to branch pipe **76** and is configured to be capable of adjusting its opening degree in response to a control signal received from controller **100**B. It should be noted that oil regulating valve **78** may be a simple valve which only performs opening and closing operations.

When compressor **10** stops its operation, controller **100**B performs a control for increasing the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator). Specifically, when compressor **10** stops, and when the heating operation is resumed after the defrosting operation ends, controller **100**B controls oil regulating valve **78** assuming the closed position to assume an open position. In response, the high-temperature and high-pressure gaseous refrigerant and liquid mixture output from compressor **10** are partially supplied from branching portion **72** of pipe **90** through branch pipe **76** to internal heat exchanger **70**, and exchange heat with the low-temperature and low-pressure gaseous refrigerant and liquid mixture output from expansion valve **30**.

The low-temperature and low-pressure gaseous refrigerant and liquid mixture output from expansion valve **30** absorb heat in internal heat exchanger **70** and are thereby increased in degree of dryness and thus flow into outdoor heat exchanger **40** (or the evaporator). This increases the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) and hence the amount of the oil retained in outdoor heat exchanger **40** (or the evaporator). Once the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) has reached a target value, controller **100**B closes oil regulating valve **78**, and stops compressor **10**, resumes the heating operation, etc.

The remainder in configuration of refrigeration cycle apparatus **1**B is identical to that of refrigeration cycle apparatus **1** of the first embodiment shown in FIG. **1**.

Refrigeration cycle apparatus **1**B having the configuration shown in FIG. **15** is provided with branch pipe **76** and has oil regulating valve **78** opened (1) when stopping the operation of compressor **10**, (2) when starting the operation of compressor **10**, and (3) when resuming the heating operation after the defrosting operation. Thus, liquid back to compressor **10** is suppressed.

That is, in any of cases (1) to (3) above, oil regulating valve **78** is opened to increase the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator). This increases the degree of superheat at the inlet of compressor

10 and suppresses liquid back to compressor **10**. Representatively, the control performed when (3) resuming the heating operation after the defrosting operation will be described.

FIG. **16** is a flowchart of a procedure of a process performed by controller **100**B in the second embodiment when resuming the heating operation after the defrosting operation. Referring to FIG. **16**, this flowchart corresponds to the flowchart shown in FIGS. **12-14** according to the first embodiment with steps S**130** and S**180** replaced with steps S**132** and S**182**, respectively. It should be noted that step S**148** in FIG. **16** represents steps S**142** S**144** and S**146** of FIGS. **12** to **14** collectively.

When controller **100**B determines in step S**110** that the condition for switching from the defrosting operation to the heating operation is established (YES in step S**110** controller **100**B switches four-way valve **91** to change a direction in which the refrigerant is passed from the direction indicated by arrow B to the direction indicated by arrow A (step S**120**). Subsequently, controller **100**B opens oil regulating valve **78** provided at branch pipe **76** and currently assuming the closed position (step S**130**). Thus, liquid back to compressor **10** is suppressed, as has been discussed above. After step S**132** is performed, controller **100**B shifts the process to step S**148**. In step S**148** controller **100**B performs a control to increase the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator). Specifically, controller **100**B may decrease the opening degree of expansion valve **30** (see step S**20** in FIG. **7**) or may increase the operating frequency of compressor **10** (see step S**21** in FIG. **8**) or may increase the rotation speed of outdoor unit fan **42** (see step S**22** in FIG. **9**).

Furthermore, if controller **100**B determines in step S**170** that the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) is equal to or larger than the target value (YES in step S**170**), controller **100**B closes oil regulating valve **78** provided at branch pipe **76** (step S**182**).

Note that the steps other than steps S**132** and S**182** are identical to those of the flowchart shown in each of FIGS. **12-14**.

Note that an additional regulating valve may further be provided to pipe **90** between branching portion **72** and confluence portion **74**, and when oil regulating valve **78** provided at branch pipe **76** is open the additional regulating valve may be closed whereas when oil regulating valve **78** is closed the additional regulating valve may be opened. This allows the entire amount of the high-temperature and high-pressure gaseous refrigerant and liquid mixture output from compressor **10** to be passed through internal heat exchanger **70** to increase the amount of heat exchanged in internal heat exchanger **70**.

While in the above description internal heat exchanger **70** is provided to pipe **94** and pipe **90** is provided with branch pipe **76**, internal heat exchanger **70** may be provided to pipe **90** and pipe **94** may be provided with a branch pipe. Alternatively, pipes **90**, **94** may not be provided with internal heat exchanger **70** and pipes **90**, **94** may each be provided with a branch pipe connected to internal heat exchanger **70**.

Thus, in the second embodiment, by providing internal heat exchanger **70**, the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) can be increased. Furthermore, by internal heat exchanger **70**, the amount of oil retained in indoor heat exchanger **20** (or the condenser) can be decreased and the amount of oil flowing into outdoor heat exchanger **40** (or the evaporator) can be increased.

According to refrigeration cycle apparatus **1**B of the second embodiment, when resuming the heating operation after the defrosting operation ends, in particular, the amount of oil returned to compressor **10** can be increased and liquid back to compressor **10** can also be suppressed. As a result, a shortage of oil in the compressor that can occur when resuming the heating operation can be suppressed, and the compressor can be operated reliably.

Third Embodiment

In a third embodiment, an oil separator is provided to pipe **90** receiving the high-temperature and high-pressure gaseous refrigerant and high-oil-concentration liquid mixture output from compressor **10**, and when stopping compressor **10**, the high-temperature and high-pressure, and high-oil-concentration liquid mixture separated by the oil separator is supplied to the input side of outdoor heat exchanger **40** (or the evaporator). Thus, before stopping compressor **10**, when resuming the heating operation after the defrosting operation is completed, etc., the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) is increased and a high-oil-concentration liquid mixture is also supplied from the oil separator to outdoor heat exchanger **40** (or the evaporator). As a result, when compressor **10** stops or after the defrosting operation ends, the lubricating oil is retained in outdoor heat exchanger **40** (or the evaporator), and when the operation of compressor **10** is started or the heating operation is resumed, returning the oil to compressor **10** in a sufficient amount is ensured.

FIG. **17** generally shows a configuration of a refrigeration cycle apparatus according to the third embodiment. With reference to FIG. **17**, this refrigeration cycle apparatus **1**C is different from refrigeration cycle apparatus **1** of the first embodiment shown in FIG. **1** in that instead of bypass pipe **62**, oil regulating valve **64** and controller **100**, refrigeration cycle apparatus **1**C comprises an oil separator **80**, an oil returning pipe **82**, an oil regulating valve **84**, and a controller **100**C.

Pipe **98** supplies four-way valve **91** with the refrigerant output from compressor **10**. Oil separator **80** is provided to pipe **98**. Pipe **94** supplies outdoor heat exchanger **40** with the refrigerant output from expansion valve **30**. Oil returning pipe **82** interconnects oil separator **80** and pipe **94** and is provided to output to pipe **94** the lubricating oil separated by oil separator **80**. Oil regulating valve **84** is provided to oil returning pipe **82**. Controller **100**C in the heating preparation control performs control to change the state of oil regulating valve **84** from the closed state to the open state.

Pipe **97** in the heating operation supplies compressor **10** with the refrigerant output from outdoor heat exchanger **40**. Bypass pipe **87** interconnects pipe **97** and a portion of oil returning pipe **82** between oil separator **80** and oil regulating valve **84**.

Oil separator **80** is provided to a pipe interconnecting the outlet of compressor **10** and four-way valve **91**, and separates the high-temperature and high-pressure gaseous refrigerant and high-oil-concentration liquid mixture output from compressor **10**. Oil returning pipe **82** interconnects oil separator **80** and confluence portion **85** provided to pipe **94**. Oil regulating valve **84** is provided to oil returning pipe **82** and is configured to be capable of adjusting its opening degree in response to a control signal received from controller **100**C. It should be noted that oil regulating valve **84** may be a simple valve which only performs opening and closing operations.

When the refrigerant flows in the direction indicated by arrow A, the high-temperature and high-pressure gaseous refrigerant separated by oil separator **80** is output to pipe **90**. The high-oil-concentration liquid mixture separated from the gaseous refrigerant in oil separator **80** is supplied to confluence portion **85** of pipe **94** through oil returning pipe **82** when oil regulating valve **84** is open.

When compressor **10** stops, or when the heating operation is resumed after the defrosting operation ends, etc., controller **100**C performs control for increasing the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator). Specifically, controller **100**C change the state of oil regulating valve **84** from the closed state to an open state when stopping compressor **10**. In response, the high temperature and high-oil-concentration liquid mixture separated in oil separator **80** is supplied from oil separator **80** through oil returning pipe **82** to confluence portion **85** of pipe **94** and interflows with the low-temperature and low-pressure gaseous refrigerant and low-oil-concentration liquid mixture output from expansion valve **30**. Thus, the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) increases, and the high-oil-concentration liquid mixture taken out from compressor **10** is supplied to outdoor heat exchanger **40** (or the evaporator). Once the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) has reached a target value, controller **100**C stops compressor **10**.

The remainder in configuration of refrigeration cycle apparatus **1**C is identical to that of refrigeration cycle apparatus **1** of the first embodiment shown in FIG. **1**.

FIG. **18** is a flowchart of a procedure of a process performed by controller **100**C in the third embodiment when resuming the heating operation after the defrosting operation. Referring to FIG. **18**, this flowchart corresponds to the flowchart shown in FIGS. **12**-**14** according to the first embodiment with steps S**130** and S**180** replaced with steps S**134** and S**184**, respectively. It should be noted that step S**148** in FIG. **16** represents steps S**142**, S**144**, and S**146** of FIGS. **12** to **14** collectively.

When controller **100**C determines in step S**110** that the condition for switching from the defrosting operation to the heating operation is established (YES in step S**110**), controller **100**C switches four-way valve **91** to change a direction in which the refrigerant is passed from the direction indicated by arrow B to the direction indicated by arrow A (step S**120**). Subsequently, controller **100**C opens oil regulating valve **84** provided at oil returning pipe **82** and currently assuming the closed position (step S**134**). This suppresses liquid back to compressor **10** and also increases the amount of oil returned to compressor **10**, as has been discussed above. After step S**134** is performed, controller **100**C shifts the process to step S**148**. In step S**148** controller **100**C performs a control to increase the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator). Specifically, controller **100**C may decrease the opening degree of expansion valve **30** (see step S**20** in FIG. **7**) or may increase the operating frequency of compressor **10** (see step S**21** in FIG. **8**) or may increase the rotation speed of outdoor unit fan **42** (see step S**22** in FIG. **9**).

Furthermore, if controller **100**C determines in step S**170** that the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) is equal to or larger than the target value (YES in step S**170**), controller **100**C closes oil regulating valve **84** provided at oil returning pipe **82** (step S**184**).

Note that the steps other than steps S**134** and S**184** are identical to those of the flowcharts shown in FIGS. **12**-**14**.

According to refrigeration cycle apparatus **1**C of the third embodiment, when resuming the heating operation after the defrosting operation ends, in particular, the amount of oil returned to compressor **10** can be increased and liquid back to compressor **10** can also be suppressed. As a result, a shortage of oil in the compressor that can occur when resuming the heating operation can be suppressed, and the compressor can be operated reliably.

Fourth Embodiment

In the third embodiment, the high-oil-concentration liquid mixture separated in oil separator **80** is supplied to the input side of outdoor heat exchanger **40** (or the evaporator) through oil returning pipe **82**. In a fourth embodiment, a configuration is adopted in which the high-oil-concentration liquid mixture separated in oil separator **80** is directly returned to compressor **10**. This can reduce the amount of oil taken out to the refrigerant circuit, and allows compressor **10** to operate more reliably.

FIG. **19** generally shows a configuration of a refrigeration cycle apparatus **1**D according to the fourth embodiment of the present invention. Referring to FIG. **19**, this refrigeration cycle apparatus **1**D has the configuration of refrigeration cycle apparatus **1**C shown in FIG. **17** plus a branching portion **86**, a bypass pipe **87**, and a confluence portion **88**.

Branching portion **86** is provided to oil returning pipe **82** between oil separator **80** and oil regulating valve **84**. Bypass pipe **87** interconnects branching portion **86** and confluence portion **88** provided to pipe **96**. By providing such a bypass pipe **87**, during a normal operation with oil regulating valve **84** closed, the liquid mixture separated in oil separator **80** is returned to compressor **10** through oil returning pipe **82**, branching portion **86**, bypass pipe **87**, and confluence portion **88**. Furthermore, the liquid mixture separated by oil separator **80** is also partially returned to compressor **10** through bypass pipe **87** when oil regulating valve **84** is opened as has been described in the third embodiment.

Thus, according to the fourth embodiment, the amount of oil taken to the refrigerant circuit can be reduced and sufficient lubrication of compressor **10** can be ensured to allow compressor **10** to operate more reliably.

It should be noted that each of the above-described embodiments and each exemplary variation can be combined as appropriate. By combining some of the embodiments or exemplary variations, when stopping compressor **10**, the degree of superheat at the outlet of outdoor heat exchanger **40** (or the evaporator) can rapidly be increased and the amount of oil retained in outdoor heat exchanger **40** (or the evaporator) can rapidly be increased. Further, when starting the operation of compressor **10**, liquid back to compressor **10** can be reliably suppressed and the amount of oil returned to compressor **10** can also further be increased.

It should be understood that the embodiments disclosed herein have been described for the purpose of illustration only and in a non-restrictive manner in any respect. The scope of the present invention is defined by the terms of the claims, rather than the embodiments description above, and is intended to include any modifications within the meaning and scope equivalent to the terms of the claims.

REFERENCE SIGNS LIST

1, **1**B, **1**C, **1**D; refrigeration cycle apparatus; **10**: compressor; **20**: indoor heat exchanger; **22**: indoor unit fan; **30**: expansion valve; **40**: outdoor heat exchanger; **42**: outdoor unit fan; **52**: pressure sensor; **54**: temperature sensor; **60**, **72**,

86: branching portion; **62**, **87**: bypass pipe; **64**, **78**, **84**: oil regulating valve; **66**, **74**, **85**, **88**: confluence portion; **70**: internal heat exchanger; **76**: branch pipe; **80**: oil separator; **82**: oil returning pipe; **90**, **92**, **94**, **96**: pipe; **91**: four-way valve; **100**, **100**B, **100**C: controller.

The invention claimed is:

1. A refrigeration cycle apparatus comprising:

a compressor configured to compress refrigerant;

a first heat exchanger;

a second heat exchanger;

an expansion valve disposed in a refrigerant path interconnecting the first heat exchanger and the second heat exchanger;

a four-way valve configured to switch a direction of flow of the refrigerant between a first direction and a second direction, in the first direction the refrigerant output from the compressor being supplied to the first heat exchanger and the refrigerant being returned to the compressor from the second heat exchanger, in the second direction the refrigerant output from the compressor being supplied to the second heat exchanger and the refrigerant being returned to the compressor from the first heat exchanger;

a controller configured to control the four-way valve to switch an operation from a defrosting operation in which the refrigerant flows in the second direction, to a heating operation in which the refrigerant flows in the first direction, to perform a heating preparation control for increasing a degree of superheat of the refrigerant returned to the compressor from the second heat exchanger, and thereafter to start the heating operation;

a first pipe configured to supply the four-way valve with refrigerant output from the compressor;

an oil separator provided to the first pipe;

a second pipe configured to supply the second heat exchanger with refrigerant output from the expansion valve;

a third pipe for interconnecting the oil separator and the second pipe and outputting to the second pipe a lubricating oil separated by the oil separator; and

a regulating valve provided to the third pipe,

wherein the heating preparation control comprises a control changing a state of the regulating valve from a closed state to an open state.

2. The refrigeration cycle apparatus according to claim **1**, further comprising:

a fourth pipe configured to supply the compressor with refrigerant output from the second heat exchanger in the heating operation; and

a bypass pipe configured to interconnect the fourth pipe and a portion of the third pipe between the oil separator and the regulating valve.

3. The refrigeration cycle apparatus according to claim **1**, wherein the heating preparation control further comprises a control to change an opening degree of the expansion valve in a closing direction.

4. The refrigeration cycle apparatus according to claim **1**, wherein the heating preparation control further includes a control to change an operating frequency of the compressor in a direction to increase the operating frequency of the compressor.

5. The refrigeration cycle apparatus according to claim **1**, further comprising a fan that blows air to the second heat exchanger, wherein the heating preparation control further comprises a control to change a rotation speed of the fan in a direction to increase the rotation speed of the fan.

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